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COMPUTER PROGRAM FOR PREDICTING THE REDUCTION OF PINK BOLLWORM POPULATIONS BY CHEMICALLY TERMINATING LATE-SEASON BOLLS IN COTTON

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ABSTRACT

B. A. Kimball, D. L. Kittock, T. J. Henneberry, and L. A. Bariola. Computer Program for Predicting the Reduction of Pink Bollworm Populations by Chemically Terminating Late-Season Bolls in Cotton. U.S. Department of Agriculture, Agricultural Research Service ARS W-48, 48 pp., September 1977.

Diapausing pink bollworms, *Pectinophora gossypiella* (Saunders), develop in unharvested immature cotton bolls late in the growing season. Consequently, eliminating these bolls by chemical termination has proven to be an effective control method. However, if the chemical treatment is applied too early in the season, some bolls that should have contributed to the yield may also be eliminated; so timing of the chemical application is important. Therefore, a computer model was developed for predicting the effects on pink bollworm populations and on cotton yields of terminating boll development with chemicals applied on any given date during the growing season.

The program listing is presented along with flow diagrams and a description of how it works. The program requires field data on the daily boll set rate for a particular cotton variety, on the rate at which the bolls mature during the season, on the reduction of boll set by a particular chemical, and on the seasonal patterns of bollworm infestation and diapause transition. An example is presented of the results obtained for a specific case.

KEYWORDS: pink bollworm, *Pectinophora gossypiella* (Saunders); chemical termination; cotton, *Gossypium hirsutum* L.; diapause, computer program; computer model; simulation; 2,4-D, (2,4-dichlorophenoxy) acetic acid; chlorflurenol, methyl 2-chloro-9-hydroxyfluorene-9-carboxylate; and Pennwalt TD-1123, potassium 3,4-dichloroisothiazole 5-carboxylate

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COMPUTER PROGRAM FOR PREDICTING THE REDUCTION OF PINK BOLLWORM POPULATIONS BY CHEMICALLY TERMINATING LATE-SEASON BOLLS IN COTTON

By B. A. Kimball, D. L. Kittock, T. J. Henneberry,
and L. A. Bariola[1]

THEORY OF FIELD METHOD

The larvae of the pink bollworm, *Pectinophora gossypiella* (Saunders), feed in green cotton bolls. When the larvae mature, they "cut out" and drop to the ground, where, in summer, they pupate. However, starting in September, progressively larger numbers of the larvae do not pupate, but instead enter the diapause or overwintering stage. These diapausing larvae develop in late-season green bolls, which usually do not mature by harvesttime. These bolls can be eliminated by early defoliation, desiccation, or early termination of irrigation. However, these practices affect maturation of all bolls, and, consequently, cotton yield and quality are reduced. A less severe treatment was proposed by Kittock et al. (*4*, *5*, *6*)[2] and Mauney et al. (*7*). They applied growth regulators to eliminate the late-season green bolls, but allowed bolls already set to continue their development and be harvested. Bariola et al. (*1*) showed that applications of certain of these chemicals reduced the number of immature green bolls and the number of diapausing pink bollworm larvae with little or no reduction of yield. The purpose of this computer program is to predict the diapausing pink bollworm population, the reduction in cotton yield when such chemicals are applied to cotton, and the optimum time to apply these chemicals.

DESCRIPTION OF COMPUTER MODEL

Figures 1 and 2 (Kittock, unpublished) illustrate how various cotton varieties set bolls during a season. Figure 3 shows the length of time required for the bolls to mature. The bolls mature faster at the higher temperatures present early in the season, and slower later in the season. However, the bolls set on any particular day do not all mature at exactly the same rate but instead are normally distributed about a mean rate (fig. 4).

Thus, the curve shows when 50 percent of the bolls set on any particular day will have matured, and a normal distribution is superimposed on this curve. By summing the contributions from all previous days, the number of bolls maturing on a particular day is computed. By accumulating the number of bolls maturing each day through the season, the final yield, in bolls per acre, is obtained.

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[1] Kimball is a soil scientist, U.S. Water Conservation Laboratory; Kittock is an agronomist, University of Arizona Cotton Research Center; and Henneberry and Bariola are entomologists, Western Cotton Research Laboratory. All authors are with the Agricultural Research Service, Phoenix, Ariz.

[2] Italic numbers in parentheses refer to Literature Cited, p. 17.

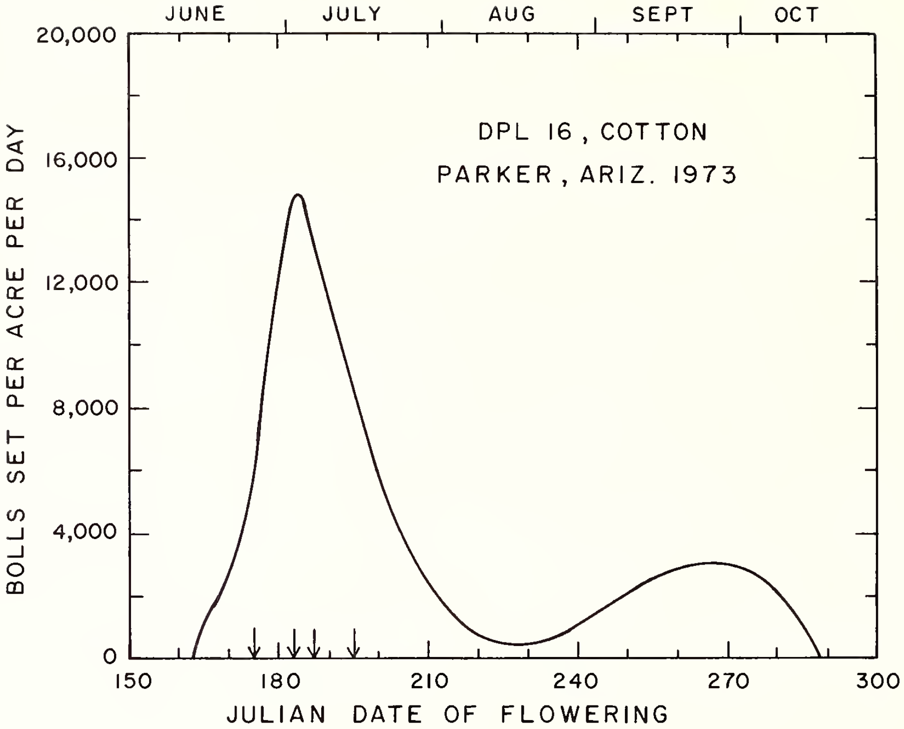

Figure 1.--Boll set versus time during season for DPL 16 cotton. The curve is based on 1973 data from Parker, Ariz. The arrows indicate the knot positions, which delimit the subranges used with the cubic spline smoothing.

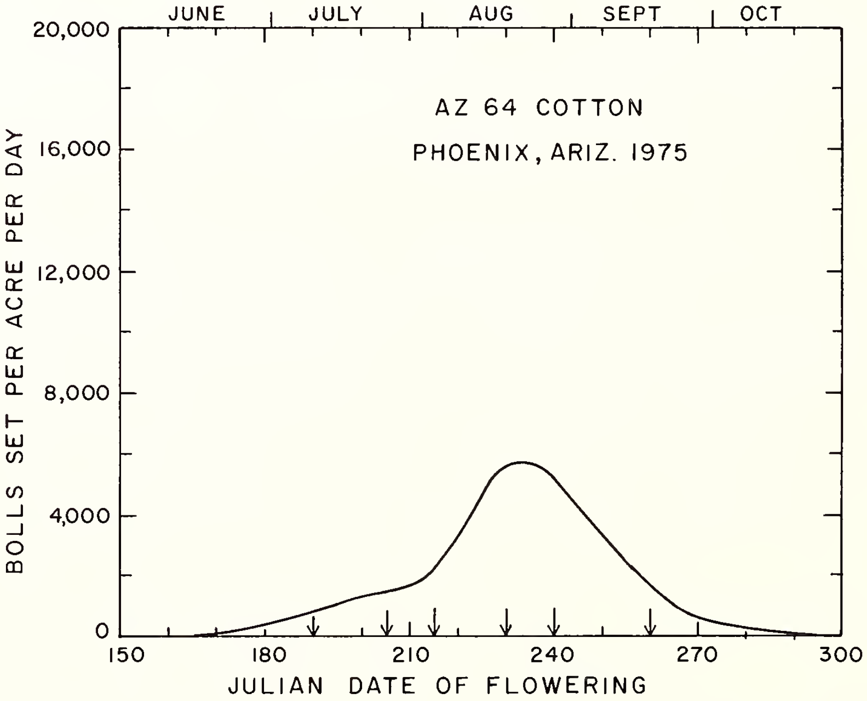

Figure 2.--Boll set versus time during season for AZ 64 cotton. The curve is based on 1975 data from Phoenix, Ariz.

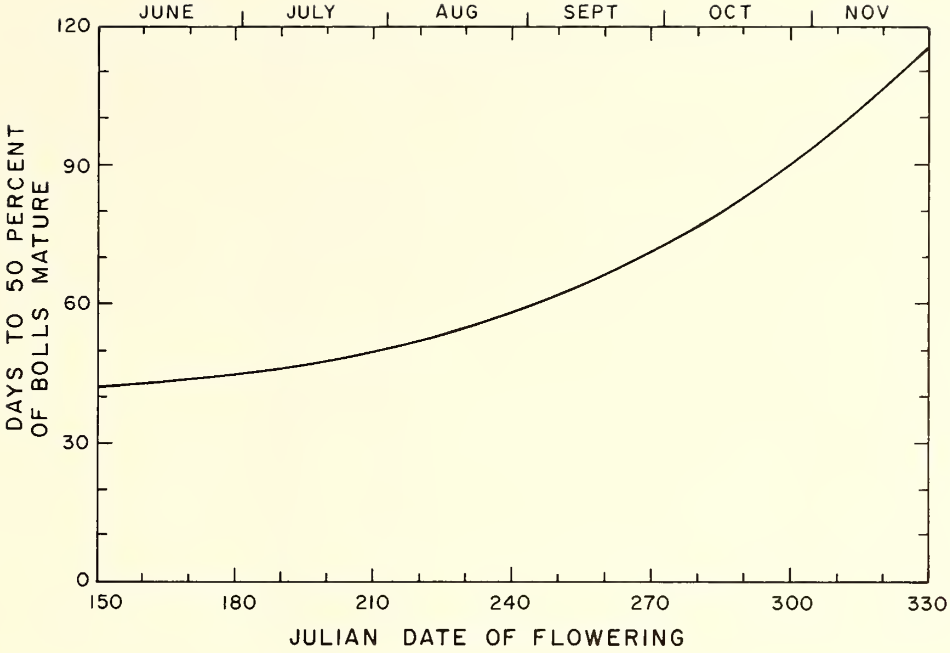

Figure 3.--Time required for 50 percent of the bolls to reach maturity versus time during the season when the bolls were set.

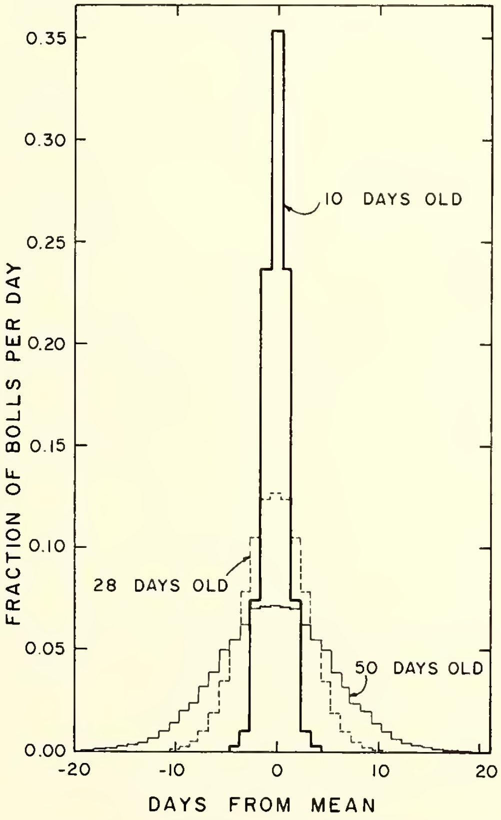

Figure 4.--Distribution curves used to model the differing physiological maturation rates of cotton bolls.

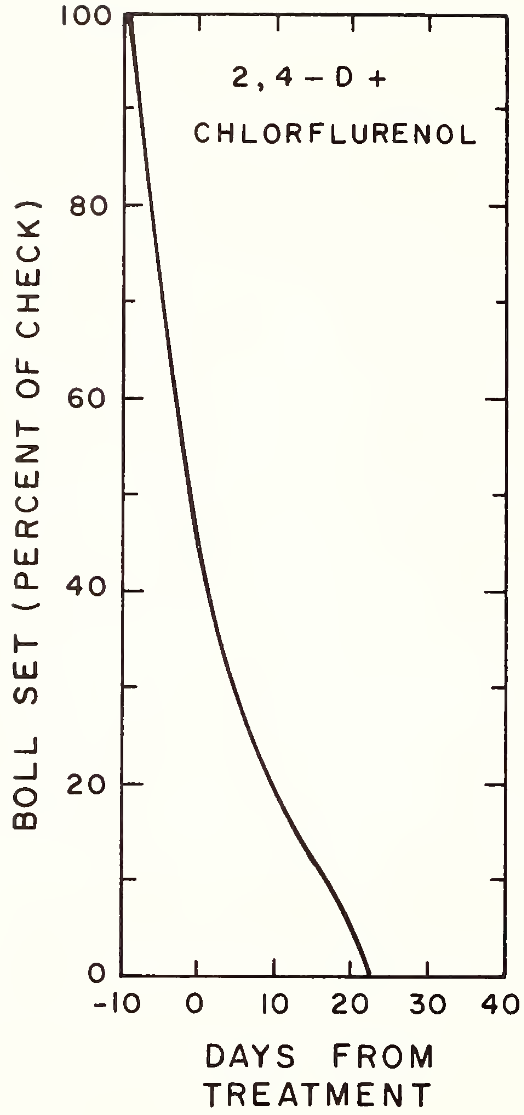

Figure 5.--Reduction in boll set of cotton caused by a treatment with 2,4-D plus chlorflurenol versus time from day of treatment.

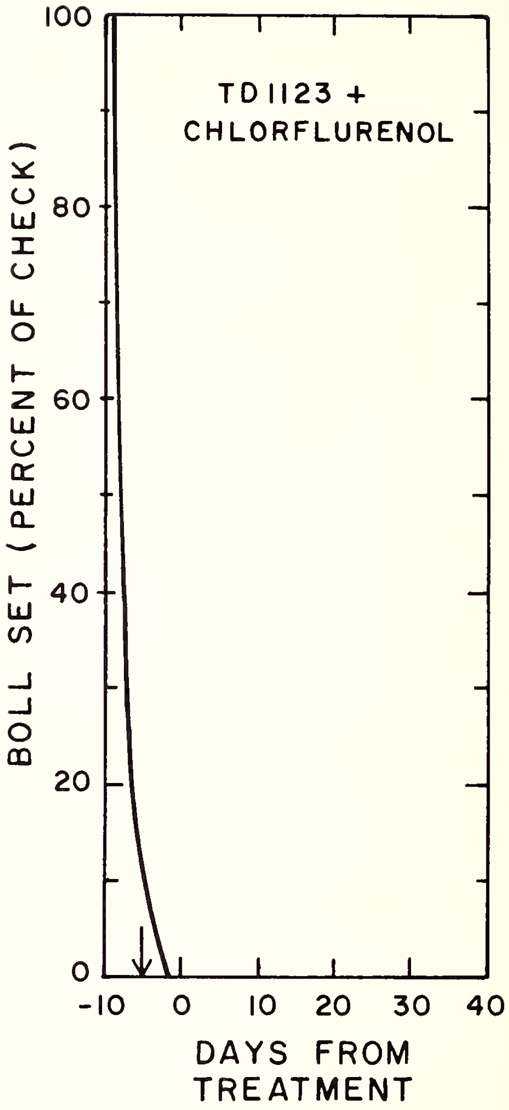

Figure 6.--Reduction in boll set of cotton caused by a treatment with TD-1123 plus chlorflurenol versus time from day of treatment.

Figures 5 and 6 (Kittock, unpublished) show how boll set is affected as a function of days from time of chemical treatment.

A new boll set pattern is obtained, but the yield is obtained by the same procedure as explained above for no chemical treatment. The chemical names of the compounds used are: 2,4-D, (2,4-dichlorophenoxy) acetic acid; chlorflurenol, methyl 2-chloro-9-hydroxyfluorene-9-carboxylate; and Pennwalt TD-1123, potassium 3,4-dichloroisothiazole 5-carboxylate.

The number of pink bollworm larvae is more difficult to compute but can be obtained using infestation data and some assumptions. Figures 7 and 8 (Vail et al., *8*) show the typical number of larvae per green boll as a function of time during the season.

Thus, if we can compute the number of green bolls in a field, for similar infestation conditions we can compute the number of larvae in the field as a function of time during the season. Figure 9 shows the fraction of the larvae going into diapause as a function of the time of year (Bariola, unpublished). Thus, once the number of larvae in a field is obtained, the number of diapaused larvae can also be obtained.

First, the number of green bolls is computed. Only green bolls are susceptible to the larvae. The age span of the susceptible bolls was found to be 10 to 28 days early in the season. Since bolls mature more slowly later in the season, we assumed that late-season bolls will require more than 10 days to become susceptible and that they will remain susceptible beyond the age of 28 days. Therefore, the first age of susceptibility is computed as IYNG[3] = 10. * (AVDA/45.) and the final age as IOLD = 28. * (AVDA/45.) where AVDA is the average number of days required for the particular day's bolls to mature. The normalizing value of 45. comes from the fact that about 45 days are required for early season bolls to mature (fig. 3).

Just as there is a normal distribution of maturation rates that must be used to compute the lengths of time required to reach full maturation, it is plausible that there is also an age distribution for becoming susceptible to pink bollworm and another for ceasing to be susceptible to pink bollworm. As shown in figure 4, for maturation at a mean of 50 days, 90 percent of the bolls mature between 41 and 59 days, which corresponds to a standard deviation of 5.47 days. This curve is based on field data (Kittock, unpublished). The bolls with this maturation distribution were all set on the same day, so an initial rectangular "pulse" has become smeared into a flattened bell after a mean of 50 days. It is plausible that the standard deviation of this boll distribution changes in proportion to the mean. Thus, we compute the standard deviation, SIGMA, for maturation distribution as SIGMA = (AVDA/50.) *5.47. Similarly, we compute its standard deviation for the first susceptibility to pink bollworm attack as SIGMA = (IYNG/50.) *5.47, and for cessation of susceptibility as SIGMA = (IOLD/50.) *5.47. The resultant distributions for means of 10 and 28 days are plotted in figure 4. The 10-day curve shows 98 percent become susceptible between 8 and 12 days of age, and the 28-day curve shows 93 percent cease to be susceptible between 23 and 33 days of age.

From the rate of maturation and its distribution, as described in the previous two paragraphs, the number of susceptible green bolls can be computed. This is done by establishing three computational loops. The outermost loop is for days through the season indexed by the symbol IDATE. The next loop sums the contribution to the green boll population present on IDATE from all days previous to IDATE. The second loop is indexed by JDATE. The innermost loop indexed by IGRN computes the number of IGRN-days-old bolls that were set on JDATE and are in the susceptible boll population present on IDATE.

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[3] The symbolic names of variables used in the FORTRAN computer program are listed and defined in the Nomenclature section of the Appendix, p. 18.

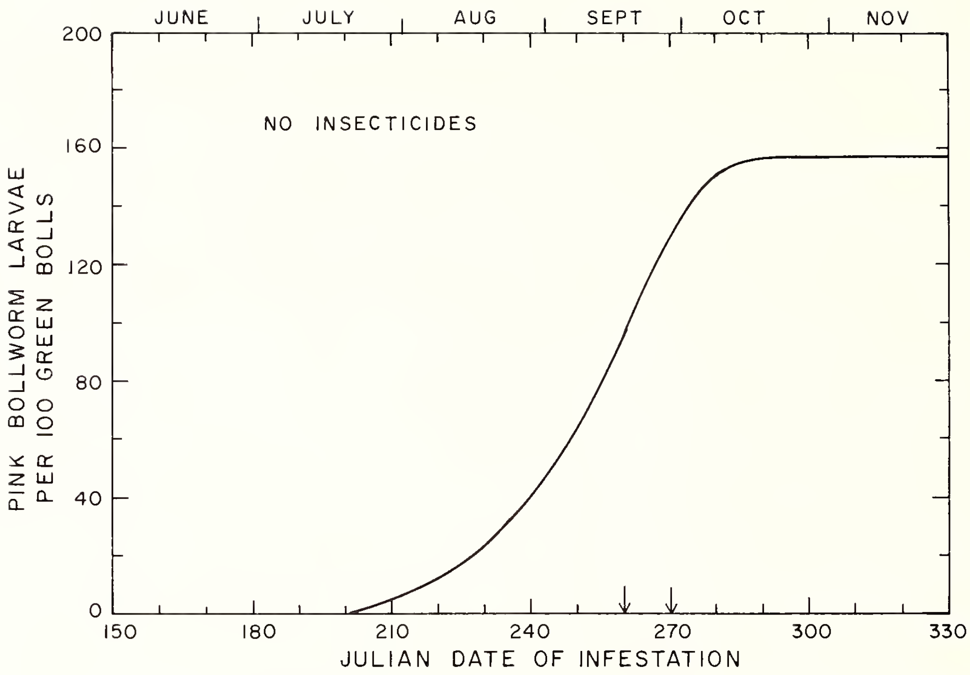

Figure 7.--Curve showing the increasing infestation of green cotton bolls with pink bollworm larvae during the growing season for a field that received no application of insecticides.

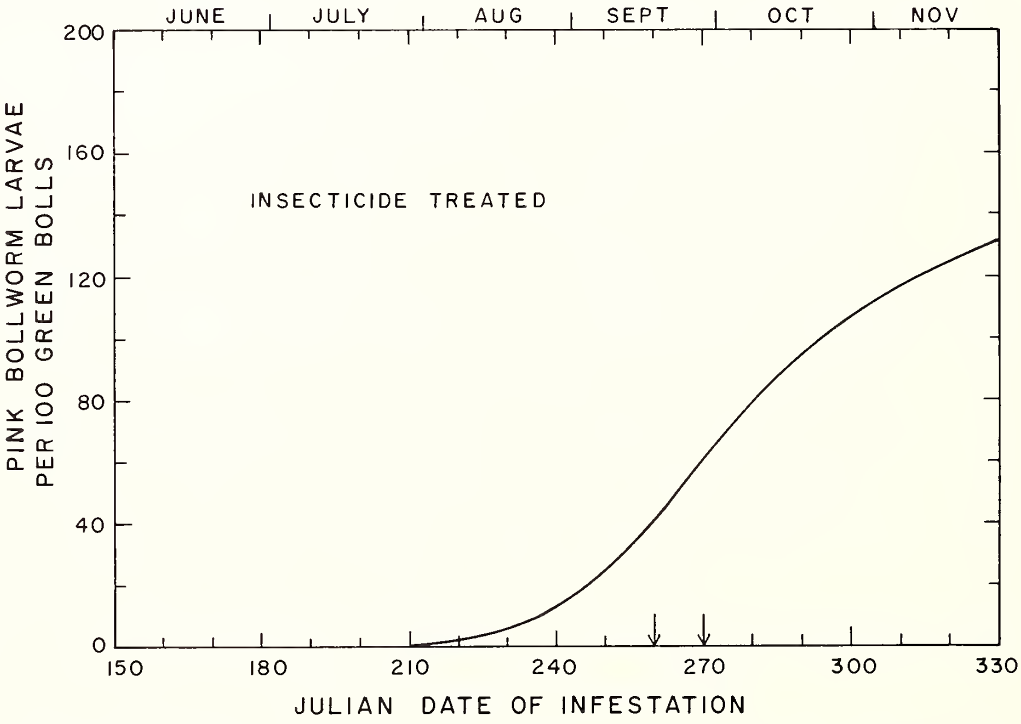

Figure 8.--Curve showing the increasing infestation of green cotton bolls with pink bollworm larvae during the growing season for a field that received applications of insecticides.

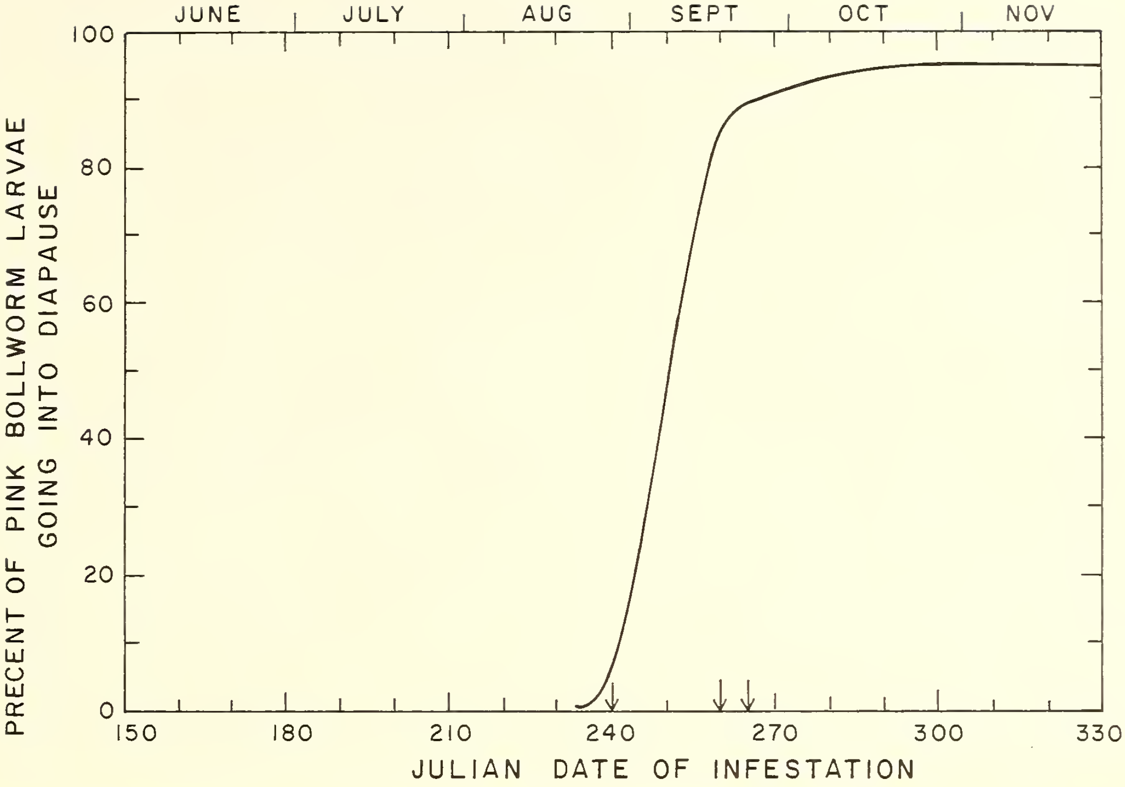

Figure 9.--Curve showing the percentage of pink bollworm larvae going into diapause versus time during the growing season when the larvae infested a green cotton boll.

As shown in flow diagrams in the Appendix, the number of IYNG bolls is computed first. The standard deviation of this group of bolls is obtained from SIGMA = (IGRN/50.) *5.45 as explained above, where IGRN = IYNG the first time through the loop. Then utilizing an error function table, the fraction (F), which these bolls represent of those set on JDATE, is computed as the area under the normal distribution curve for this particular mean boll age. The integration limits go from JDIF - 0.5 to JDIF + 0.5 days, where JDIF = JDATE + IGRN - IDATE, the difference between IDATE and the mean age of these bolls. As the innermost loop is repeated for each green boll age (IGRN), F is obtained for each age and is multipled by the boll set number for JDATE to get the number of each age of bolls contributed by JDATE. The same F's are used to obtain the green boll numbers for when chemical treatments were applied by using the corresponding reduced boll set number for JDATE obtained earlier to account for chemical treatments. The green boll numbers without and with chemical treatments are stored in arrays, which are indexed by IGRN. Each element stores the accumulation of IGRN day-old bolls from previous days (JDATE) to the population present on IDATE.

After the population of green bolls has been obtained for IDATE, the amount of new infestation of pink bollworms is computed for the case of no chemical treatment. Using the infestation curve (figs. 7 and 8), the number of new pink bollworm larvae is computed as the sum of the average fraction for IDATE (directly from the infestation curve), times the number of green bolls that have become newly susceptible, plus the change in infestation since the previous day, times the number of all other ages of susceptible green bolls. This procedure is valid only for the check field with no chemical termination treatment because the infestation curves came from such untreated fields, which have a different green boll age distribution than the treated fields.

Once the total number of new pink bollworm larvae (PNEW) has been computed for the case of no chemical termination treatment, an adjustment is made to obtain the number of new pink bollworm larvae (CPNEW) for the case where there is a treatment. First, we assume there is an equal probability for all susceptible green bolls to be infested with new larvae. The amount of new infestation per boll is PNEW/TGBLS, where TGBLS is the total number of green bolls. The number of new larvae in a particular age of boll (PVBVD) is then simply the number of bolls of that age times PNEW/TGBLS. We next assume that when the chemical treatment removes green bolls, the pink bollworm population is reduced proportionately and infestation of remaining bolls does not increase. Kittock et al. (*4*) have shown this is a reasonable assumption. Thus, assuming that the pink bollworm population is reduced proportional to the green boll reduction, CPNEW is computed as the sum of over boll age of PVBVD times the ratio of number of green bolls with to without chemical treatment of each boll age.

Finally, after the amounts of new infestation without and with a chemical termination treatment have been computed for IDATE, the fraction going into a diapause is computed from the diapause curve (fig. 9). Then, the total number going into diapause is accumulated through the season as IDATE steps along day by day.

INPUT CURVES AND FIGURES FROM FIELD DATA

Since various types of cotton have various patterns of setting bolls through a season, and since different chemical treatments affect boll set differently, we decided at the outset that the various input curves should be represented by individual subroutines. This method allows the same program to be used while only substituting one subroutine for another as one changes from one case to another.

The subroutines are all similar in that all have two arguments. The first is a number or a date given to the subroutine by the main calling program, and the second is a value computed by the subroutine and returned to the main program.

The data in all figures (except fig. 4) have been approximated using smooth curves. The method of smoothing was that of cubic splines (Kimball, *2*, *3*), which fits cubic polynomials to subranges of the data. The end points of the subranges are called knots and are indicated by arrows in the figures. Each subrange of data has a cubic equation that was fitted subject to the constraints that it must have the same function value and the same first and second derivative at the knot where it meets the cubic equation for the adjacent subrange. The values of the coefficients for a subrange of a particular curve can be obtained by looking at the subroutine for the particular curve in the program section of the Appendix, page 20. First, sort through the IF statements to find the particular subrange. Then, the numbers for the CUBIC function are the constant, linear, quadratic, and cubic coefficients, respectively. Often, the first and last subrange were deliberately set to an appropriate constant such as zero. Other smoothing methods than cubic splines can also be used, or even tabular data, so long as the subroutines have the correct name and argument format.

The curves presented here were used to represent types of data rather than to represent particular sets of data as closely as possible. Therefore, only the curves are presented, and not the original data points upon which they are based. Thus, the computed results can be regarded as typical of what to expect when the input curves are of the type shown.

Boll Set

Figure 1 shows the boll set pattern for DPL 16 (Deltapine 16) cotton obtained in 1973 at Parker, Ariz. The August slump in boll set followed by the setting of late-season bolls, many of which do not mature, makes this variety of cotton a particularly good candidate for reducing pink bollworm populations by chemical termination of the late-season bolls.

Figure 2 shows the boll set pattern for AZ 64 cotton based on 1975 data from Phoenix. This pattern represents an opposite type of cotton and growing conditions from the DPL 16 of figure 1, because a large portion of the bolls are set in late August.

SUBROUTINE BOLSET (IDATE, B) is used to compute the bollset where IDATE is the Julian date of flowering given by the main calling program, and B is the boll set per acre per day computed by BOLSET and returned to the main program.

Boll Maturation Time

Figure 3 shows the length of time for maturation required for 50 percent of the bolls set at the time during the season shown on the axis. This curve is based on 1967 data from Phoenix.

SUBROUTINE BOLMAT (IDATE, AVDA) is used to compute the length of time for boll maturation, where IDATE is the Julian date of flowering given by the calling program, and AVDA is the number of days required for 50 percent of the bolls set on IDATE to mature. AVDA is computed by BOLMAT and returned to the calling program.

Distribution of Boll Maturation Rates

Figure 4 shows three maturation rate distribution curves used by the program. These curves are not input to the program, but instead are computed by the program from values of the mean days and standard deviations. The 50-day curve is based on actual data from Phoenix in 1967. The data shows that 5 percent of the bolls matured in 41 days; 50 percent in 50 days; and 95 percent, in 59 days. The distribution appeared normal with a mean of 50 days and a standard deviation of 5.47 days. The other distributions are computed by making the standard deviation proportional to the mean age of the population, that is, $\sigma\ (\mu/50.)*5.47$. If a different maturation rate distribution is to be used, the main program will have to be changed, but this can be done.

Chemical Termination Treatments

Figures 5 and 6 show the effects of 2,4-D plus chlorflurenol and of TD-1123 plus chlorflurenol, respectively, on the boll set of cotton. Both treatments affect bolls set up to 9 days prior to the day of treatment. TD-1123 stops boll set almost immediately, whereas 2,4-D allows some bolls to set even 20 days after treatment.

SUBROUTINE CHEM (JDIF, FRACT) is used to compute the effect of the chemical treatment on boll set, where JDIF is the number of days from the date of chemical treatment given by the calling program, and FRACT is the fraction of bolls remaining. FRACT is computed by CHEM and returned to the calling program.

Infestation

Figures 7 and 8 show the buildup of pink bollworm larvae through the growing season for fields that had not received and had received, respectively, applications of insecticides for pink bollworm control. The numbers of larvae are much higher during August and September in the no insecticide fields. The last insecticide application was made on 17 September on the treated field.

SUBROUTINE INFEST (IDATE, FNST) is used to compute the infestation, where IDATE is the Julian date during the growing season given by the calling program, and FNFST is the number of pink bollworm larvae per green boll. FNFST is computed by INFEST and returned to the calling program.

Diapause

Figure 9 shows the percentage of pink bollworm larvae going into diapause versus the Julian date of infestation. The big change occurs during September, going from about 0 to 90 percent.

SUBROUTINE DIPAS (IDATE, FDIPAS) is used to compute the fraction going into diapause, where IDATE is the Julian date of infestation given by calling program, and FDIPAS is the fraction of pink bollworm larvae going into diapause that infested on IDATE. FDIPAS is computed by DIPAS and returned to the calling program.

INSTRUCTIONS FOR RUNNING PROGRAM FROM COMPUTER CONSOLE

The FORTRAN program was written for use on a Data General Corporation Nova 800 Jumbo Minicomputer with 32K of memory, movable head disk storage, and a line printer. First, the main program and all functions and subroutines are transferred to disk files and compiled. Then the main program and functions, and those subroutines needed for a particular run are loaded and executed. The program will respond with a question about output files. If the user responds with a 12, the line printer will be used for output. If the user responds with a 2, the output will be stored in the COTRSLT file by the program. Next, the computer will ask the number of runs. The answer should be the number of chemical treatment dates with which this particular subroutine package is to be run. The computer will then request chemical treatment dates, one for each run, in a day, month format. Finally, it will compute the numbers of cotton bolls and pink bollworms for each day of the season and output the results.

EXAMPLE OF PRINTED RESULTS

Figure 10 (p. 12) shows an example of the printed results obtained from the program for a run with DPL 16 cotton (fig. 1) that received no insecticide (fig. 7) but was treated with TD-1123 plus chlorflurenol (fig. 6) on Julian date 244, as indicated by the top two heading lines. The next line gives the date and time of the computer run. DA, MO, and DATE are the day, month, and Julian date through the growing season. MATR DATE is the day from fig. 3 when 50 percent of the bolls set on the Julian date will mature. IFS is the number of pink bollworm larvae infesting 100 green bolls (fig. 7), and DIPS is the percentage of newly infesting larvae going into diapause (fig. 9). BOLL SET is the number of bolls set per acre per day (fig. 1) for an untreated field (CK) and for a field treated with TD-1123 plus chlorflurenol (TMT). GREEN BOLLS, HARVEST, AND DIAPAUSE PBW are the number of susceptible green bolls, the number of mature harvestable bolls, and the number of pink bollworm larvae in diapause, respectively, per 0.01 acre for untreated (CK) and treated (TMT) fields.

Figure 11 (p. 16) is a graph of the numerical data shown in figure 10. The infestation (IFS) and diapause (DIPS) curves came from figures 7 and 9. The untreated (CK) boll set curve is the same as figure 1, whereas the treated curve shows the elimination of bolls set after about 23 August for a 1 September application of TD-1123 plus chlorflurenol. The number of susceptible green bolls in the treated field declined relative to the untreated field about 10 days later, and went to zero by about the end of September.

The results of applying TD-1123 plus chlorflurenol can be seen by comparing the number of diapausing pink bollworms for the untreated (CK) and treated (TMT) fields (figs. 10 and 11). For a harvest date of 30 November, the untreated field had 1,623 per 0.01 acre, whereas the treated field had only 112. The yield penalty caused by not allowing late-season bolls to develop can be seen by comparing the harvest bolls for the untreated (CK) and treated (TMT) fields. For the 30 November harvest date, the untreated field had 4,236 mature bolls per 0.01 acre, whereas the treated field had 3,631. This amounts to a 14.3-percent loss in yield but a gain of 93.1 percent in the reduction in the overwintering pink bollworm population, as stated at the end of figure 10.

Figure 10.--Computer output data.

```
EXAMPLE   DPL 16    NO INSECTICIDE    TD1123 + CHLORFLURENOL
DATE OF CHEMICAL TREATMENT =  244

RUN ON  14 12 76  AT   9 12 45

                           BOLL SET  GREEN BOLLS    HARVEST  DIAPAUSE PBW
           MATR IFS DIPS   CK   TMT    CK   TMT    CK   TMT    CK   TMT
DA MO DATE DATE  %   %       /A/DA     - - - - - - - -/.01A - - - - - - -
 3, 6, 154, 196,  0,  0,    0,    0,    0,    0,    0,    0,    0,    0
 4, 6, 155, 197,  0,  0,    0,    0,    0,    0,    0,    0,    0,    0
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 3, 7, 184, 229,  0,  0,14767,14767,  289,  289,    0,    0,    0,    0
 4, 7, 185, 230,  0,  0,14487,14487,  353,  353,    0,    0,    0,    0
 5, 7, 186, 232,  0,  0,13989,13989,  429,  429,    0,    0,    0,    0
 6, 7, 187, 233,  0,  0,13378,13378,  518,  518,    0,    0,    0,    0
 7, 7, 188, 234,  0,  0,12792,12792,  621,  621,    0,    0,    0,    0
 8, 7, 189, 235,  0,  0,12149,12149,  735,  735,    0,    0,    0,    0
 9, 7, 190, 236,  0,  0,11503,11503,  859,  859,    0,    0,    0,    0
10, 7, 191, 237,  0,  0,10860,10860,  991,  991,    0,    0,    0,    0
11, 7, 192, 238,  0,  0,10224,10224, 1128, 1128,    0,    0,    0,    0
12, 7, 193, 240,  0,  0, 9600, 9600, 1265, 1265,    0,    0,    0,    0
13, 7, 194, 241,  0,  0, 8991, 8991, 1398, 1398,    0,    0,    0,    0
14, 7, 195, 242,  0,  0, 8404, 8404, 1525, 1525,    0,    0,    0,    0
15, 7, 196, 243,  0,  0, 7853, 7853, 1644, 1644,    0,    0,    0,    0
16, 7, 197, 244,  1,  0, 7316, 7316, 1753, 1753,    0,    0,    0,    0
17, 7, 198, 245,  1,  0, 6804, 6804, 1725, 1725,    1,    1,    0,    0
18, 7, 199, 247,  1,  0, 6316, 6316, 1820, 1820,    1,    1,    0,    0
```

Figure 10.--Computer output data--*Continued*

```
19,  7, 200, 248,  1,  0, 5852, 5852, 1905, 1905,    2,    2,    0,    0
20,  7, 201, 249,  1,  0, 5410, 5410, 1977, 1977,    3,    3,    0,    0
21,  7, 202, 250,  2,  0, 4992, 4992, 2036, 2036,    5,    5,    0,    0
22,  7, 203, 251,  2,  0, 4596, 4596, 2081, 2081,    8,    8,    0,    0
23,  7, 204, 253,  2,  0, 4222, 4222, 2110, 2110,   12,   12,    0,    0
24,  7, 205, 254,  3,  0, 3869, 3869, 2123, 2123,   17,   17,    0,    0
25,  7, 206, 255,  3,  0, 3536, 3536, 2117, 2117,   23,   23,    0,    0
26,  7, 207, 256,  4,  0, 3224, 3224, 2095, 2095,   32,   32,    0,    0
27,  7, 208, 257,  4,  0, 2932, 2932, 2057, 2057,   42,   42,    0,    0
28,  7, 209, 259,  5,  0, 2659, 2659, 2005, 2005,   55,   55,    0,    0
29,  7, 210, 260,  5,  0, 2405, 2405, 1941, 1941,   72,   72,    0,    0
30,  7, 211, 261,  6,  0, 2169, 2169, 1868, 1868,   91,   91,    0,    0
31,  7, 212, 262,  6,  0, 1951, 1951, 1790, 1790,  114,  114,    0,    0
 1,  8, 213, 263,  7,  0, 1751, 1751, 1709, 1709,  141,  141,    0,    0
 2,  8, 214, 265,  8,  0, 1567, 1567, 1628, 1628,  173,  173,    0,    0
 3,  8, 215, 266,  8,  0, 1400, 1400, 1548, 1548,  210,  210,    0,    0
 4,  8, 216, 267,  9,  0, 1248, 1248, 1470, 1470,  253,  253,    0,    0
 5,  8, 217, 268, 10,  0, 1112, 1112, 1393, 1393,  301,  301,    0,    0
 6,  8, 218, 270, 11,  0,  991,  991, 1318, 1318,  356,  356,    0,    0
 7,  8, 219, 271, 12,  0,  884,  884, 1213, 1213,  417,  417,    0,    0
 8,  8, 220, 272, 13,  0,  791,  791, 1140, 1140,  486,  486,    0,    0
 9,  8, 221, 273, 14,  0,  711,  711, 1068, 1068,  561,  561,    0,    0
10,  8, 222, 275, 15,  0,  644,  644,  997,  997,  644,  644,    0,    0
11,  8, 223, 276, 16,  0,  590,  590,  928,  928,  733,  733,    0,    0
12,  8, 224, 277, 17,  0,  548,  548,  863,  863,  828,  828,    0,    0
13,  8, 225, 278, 18,  0,  517,  517,  802,  802,  930,  930,    0,    0
14,  8, 226, 280, 19,  0,  497,  497,  745,  745, 1035, 1035,    0,    0
15,  8, 227, 281, 20,  0,  488,  488,  692,  692, 1145, 1145,    0,    0
16,  8, 228, 282, 22,  0,  488,  488,  643,  643, 1257, 1257,    0,    0
17,  8, 229, 284, 23,  0,  498,  498,  596,  596, 1370, 1370,    0,    0
18,  8, 230, 285, 24,  0,  517,  517,  552,  552, 1484, 1484,    0,    0
19,  8, 231, 286, 26,  0,  545,  545,  509,  509, 1597, 1597,    0,    0
20,  8, 232, 288, 27,  0,  580,  580,  468,  468, 1708, 1708,    0,    0
21,  8, 233, 289, 29,  0,  623,  623,  429,  429, 1817, 1817,    0,    0
22,  8, 234, 290, 31,  0,  673,  673,  393,  393, 1923, 1923,    0,    0
23,  8, 235, 291, 32,  0,  730,  600,  353,  353, 2026, 2026,    0,    0
24,  8, 236, 293, 34,  2,  793,  366,  323,  323, 2125, 2125,    0,    0
25,  8, 237, 294, 36,  2,  861,  215,  296,  296, 2220, 2220,    0,    0
26,  8, 238, 295, 38,  3,  934,  131,  272,  272, 2310, 2310,    1,    1
27,  8, 239, 297, 40,  5, 1012,   88,  250,  250, 2397, 2397,    1,    1
28,  8, 240, 298, 42,  7, 1094,   71,  230,  230, 2478, 2478,    1,    1
29,  8, 241, 300, 44,  9, 1179,   37,  212,  212, 2556, 2556,    2,    2
30,  8, 242, 301, 46, 12, 1268,    0,  196,  196, 2629, 2629,    3,    3
31,  8, 243, 302, 48, 15, 1359,    0,  181,  181, 2698, 2698,    4,    4
 1,  9, 244, 304, 50, 19, 1453,    0,  169,  169, 2763, 2763,    5,    5
 2,  9, 245, 305, 53, 23, 1548,    0,  159,  159, 2824, 2824,    6,    6
 3,  9, 246, 306, 55, 28, 1644,    0,  151,  150, 2881, 2881,    8,    8
 4,  9, 247, 308, 57, 32, 1741,    0,  144,  143, 2935, 2935,   11,   11
 5,  9, 248, 309, 60, 37, 1838,    0,  133,  131, 2985, 2985,   12,   12
 6,  9, 249, 311, 62, 42, 1934,    0,  129,  125, 3032, 3032,   15,   15
 7,  9, 250, 312, 65, 47, 2030,    0,  127,  118, 3076, 3076,   19,   19
 8,  9, 251, 313, 68, 52, 2124,    0,  127,  112, 3117, 3117,   24,   23
 9,  9, 252, 315, 71, 56, 2217,    0,  128,  105, 3155, 3155,   29,   27
10,  9, 253, 316, 74, 61, 2308,    0,  131,   99, 3191, 3191,   36,   32
```

Figure 10.--Computer output data--*Continued*

```
11,  9, 254, 318,  76,  65, 2395,     0,  136,    92, 3224, 3224,   44,   38
12,  9, 255, 319,  79,  70, 2479,     0,  141,    86, 3255, 3255,   53,   43
13,  9, 256, 320,  83,  74, 2560,     0,  149,    81, 3283, 3283,   64,   49
14,  9, 257, 322,  86,  77, 2636,     0,  157,    75, 3310, 3310,   77,   55
15,  9, 258, 323,  89,  80, 2708,     0,  152,    70, 3334, 3334,   80,   57
16,  9, 259, 325,  92,  83, 2774,     0,  162,    65, 3357, 3357,   95,   63
17,  9, 260, 326,  96,  85, 2835,     0,  173,    61, 3378, 3378,  113,   69
18,  9, 261, 328,  99,  86, 2889,     0,  186,    56, 3397, 3397,  131,   75
19,  9, 262, 329, 103,  87, 2937,     0,  199,    52, 3415, 3415,  152,   80
20,  9, 263, 331, 106,  87, 2977,     0,  213,    47, 3431, 3431,  175,   85
21,  9, 264, 332, 110,  88, 3010,     0,  228,    43, 3446, 3446,  201,   90
22,  9, 265, 334, 113,  88, 3034,     0,  244,    38, 3460, 3460,  228,   94
23,  9, 266, 335, 117,  89, 3050,     0,  261,    34, 3472, 3472,  257,   98
24,  9, 267, 337, 120,  90, 3057,     0,  278,    29, 3484, 3484,  289,  101
25,  9, 268, 338, 123,  90, 3054,     0,  273,    25, 3494, 3494,  296,  102
26,  9, 269, 340, 127,  90, 3041,     0,  290,    21, 3504, 3504,  330,  105
27,  9, 270, 341, 130,  91, 3017,     0,  309,    17, 3512, 3512,  366,  107
28,  9, 271, 343, 132,  91, 2982,     0,  327,    14, 3520, 3520,  404,  108
29,  9, 272, 344, 135,  91, 2936,     0,  346,    11, 3528, 3528,  443,  109
30,  9, 273, 346, 138,  91, 2877,     0,  365,     8, 3535, 3535,  483,  110
 1, 10, 274, 347, 140,  92, 2806,     0,  385,     6, 3541, 3541,  525,  111
 2, 10, 275, 349, 142,  92, 2722,     0,  405,     4, 3547, 3547,  569,  111
 3, 10, 276, 350, 144,  92, 2624,     0,  396,     3, 3552, 3552,  575,  111
 4, 10, 277, 352, 145,  92, 2512,     0,  415,     2, 3558, 3558,  619,  112
 5, 10, 278, 354, 147,  93, 2385,     0,  434,     1, 3563, 3563,  664,  112
 6, 10, 279, 355, 149,  93, 2744,     0,  454,     1, 3568, 3567,  711,  112
 7, 10, 280, 357, 150,  93, 2087,     0,  473,     1, 3572, 3572,  757,  112
 8, 10, 281, 358, 151,  93, 1913,     0,  491,     0, 3577, 3576,  804,  112
 9, 10, 282, 360, 152,  93, 1724,     0,  510,     0, 3581, 3580,  852,  112
10, 10, 283, 362, 153,  94, 1517,     0,  528,     0, 3586, 3585,  900,  112
11, 10, 284, 363, 154,  94, 1293,     0,  515,     0, 3591, 3589,  903,  112
12, 10, 285, 365, 154,  94, 1050,     0,  531,     0, 3595, 3592,  951,  112
13, 10, 286, 366, 155,  94,  790,     0,  547,     0, 3600, 3596,  998,  112
14, 10, 287, 368, 156,  94,  510,     0,  563,     0, 3605, 3600, 1044,  112
15, 10, 288, 370, 156,  94,  211,     0,  577,     0, 3610, 3604, 1090,  112
16, 10, 289, 371, 156,  94,    0,     0,  591,     0, 3616, 3607, 1136,  112
17, 10, 290, 373, 156,  94,    0,     0,  603,     0, 3621, 3610, 1180,  112
18, 10, 291, 375, 157,  95,    0,     0,  585,     0, 3627, 3613, 1183,  112
19, 10, 292, 376, 157,  95,    0,     0,  596,     0, 3633, 3616, 1225,  112
20, 10, 293, 378, 157,  95,    0,     0,  605,     0, 3640, 3618, 1266,  112
21, 10, 294, 380, 157,  95,    0,     0,  613,     0, 3647, 3621, 1306,  112
22, 10, 295, 381, 157,  95,    0,     0,  619,     0, 3654, 3623, 1345,  112
23, 10, 296, 383, 157,  95,    0,     0,  624,     0, 3662, 3624, 1382,  112
24, 10, 297, 385, 157,  95,    0,     0,  603,     0, 3670, 3626, 1382,  112
25, 10, 298, 387, 157,  95,    0,     0,  605,     0, 3678, 3627, 1417,  112
26, 10, 299, 388, 157,  95,    0,     0,  606,     0, 3687, 3628, 1450,  112
27, 10, 300, 390, 157,  95,    0,     0,  604,     0, 3696, 3629, 1480,  112
28, 10, 301, 392, 157,  95,    0,     0,  600,     0, 3706, 3629, 1508,  112
29, 10, 302, 393, 157,  95,    0,     0,  595,     0, 3716, 3630, 1533,  112
30, 10, 303, 395, 157,  95,    0,     0,  587,     0, 3726, 3630, 1555,  112
31, 10, 304, 397, 157,  95,    0,     0,  564,     0, 3737, 3631, 1555,  112
 1, 11, 305, 399, 157,  95,    0,     0,  553,     0, 3749, 3631, 1574,  112
 2, 11, 306, 401, 157,  95,    0,     0,  540,     0, 3760, 3631, 1589,  112
 3, 11, 307, 402, 157,  95,    0,     0,  524,     0, 3773, 3631, 1601,  112
```

Figure 10.--Computer output data--*Continued*

```
  4, 11,  308,  404, 157,  95,     0,     0,  507,      0,  3786,  3631,  1609,    112
  5, 11,  309,  406, 157,  95,     0,     0,  483,      0,  3799,  3631,  1609,    112
  6, 11,  310,  408, 157,  95,     0,     0,  464,      0,  3813,  3631,  1615,    112
  7, 11,  311,  410, 157,  95,     0,     0,  443,      0,  3827,  3631,  1619,    112
  8, 11,  312,  411, 157,  95,     0,     0,  421,      0,  3841,  3631,  1621,    112
  9, 11,  313,  413, 157,  95,     0,     0,  399,      0,  3856,  3631,  1622,    112
 10, 11,  314,  415, 157,  95,     0,     0,  377,      0,  3872,  3631,  1622,    112
 11, 11,  315,  417, 157,  95,     0,     0,  355,      0,  3887,  3631,  1622,    112
 12, 11,  316,  419, 157,  95,     0,     0,  333,      0,  3903,  3631,  1622,    112
 13, 11,  317,  421, 157,  95,     0,     0,  311,      0,  3920,  3631,  1623,    112
 14, 11,  318,  423, 157,  95,     0,     0,  289,      0,  3937,  3631,  1623,    112
 15, 11,  319,  424, 157,  95,     0,     0,  268,      0,  3954,  3631,  1623,    112
 16, 11,  320,  426, 157,  95,     0,     0,  248,      0,  3971,  3631,  1623,    112
 17, 11,  321,  428, 157,  95,     0,     0,  228,      0,  3989,  3631,  1623,    112
 18, 11,  322,  430, 157,  95,     0,     0,  208,      0,  4007,  3631,  1623,    112
 19, 11,  323,  432, 157,  95,     0,     0,  190,      0,  4025,  3631,  1623,    112
 20, 11,  324,  434, 157,  95,     0,     0,  172,      0,  4044,  3631,  1623,    112
 21, 11,  325,  436, 157,  95,     0,     0,  154,      0,  4062,  3631,  1623,    112
 22, 11,  326,  438, 157,  95,     0,     0,  138,      0,  4081,  3631,  1623,    112
 23, 11,  327,  440, 157,  95,     0,     0,  122,      0,  4100,  3631,  1623,    112
 24, 11,  328,  442, 157,  95,     0,     0,  107,      0,  4119,  3631,  1623,    112
 25, 11,  329,  444, 157,  95,     0,     0,   94,      0,  4138,  3631,  1623,    112
 26, 11,  330,  446, 157,  95,     0,     0,   81,      0,  4158,  3631,  1623,    112
 27, 11,  331,  448, 157,  95,     0,     0,   69,      0,  4177,  3631,  1623,    112
 28, 11,  332,  450, 157,  95,     0,     0,   59,      0,  4197,  3631,  1623,    112
 29, 11,  333,  452, 157,  95,     0,     0,   49,      0,  4216,  3631,  1623,    112
 30, 11,  334,  454, 157,  95,     0,     0,   41,      0,  4236,  3631,  1623,    112

HARVEST REDUCTION        (%) =    14.3
PINK BOLLWORM REDUCTION  (%) =    93.1
```

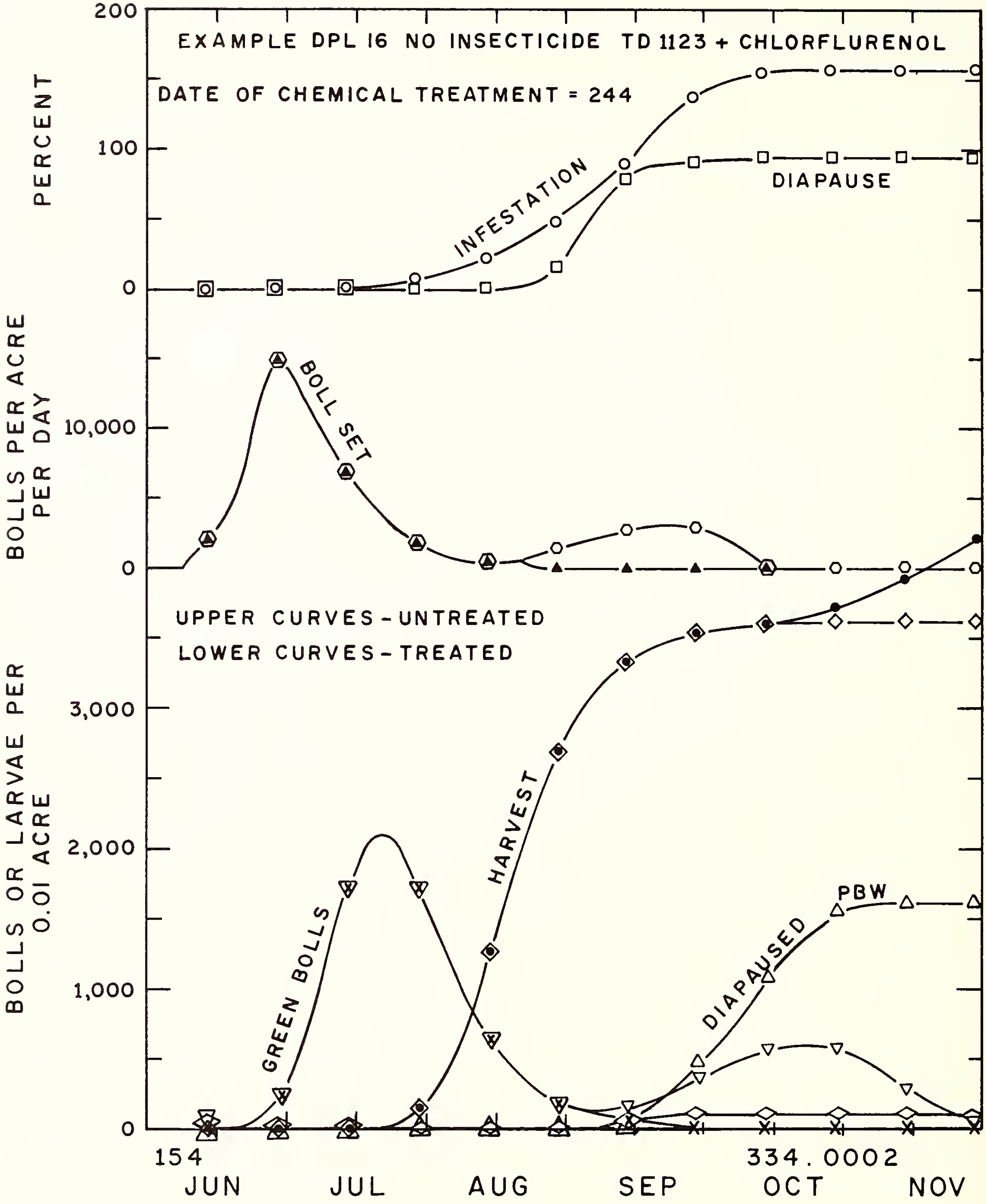

Figure 11.--Plot of the computer output data from figure 10.

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APPENDIX

Nomenclature

Symbol *Description*

A - Constant coefficient of cubic polynomial.

AVDA - Days from flowering to when 50 percent of bolls mature.

B - Bolls set per acre on IDATE.

B - Linear coefficient of cubic polynomial.

BLSET( ) - Array of bolls set per day per acre. Each element is the bolls set on the day given by the subscript.

BOLMAT - Subroutine to compute the number of days from flowering to when 50 percent of the bolls mature.

BOLSET - Subroutine to compute the bolls set per acre per day.

C - Quadratic coefficient of cubic polynomial.

CBLSET( ) - Array of bolls set per day per acre when there was a chemical treatment.

CDPBW - Number of pink bollworm larvae (per acre) in diapause from field that received chemical treatment.

CGBLS( ) - Same as GBLS but for a field with a chemical treatment.

CHEM - Subroutine to compute the fractional reduction in boll set due to a chemical treatment as a function of days from day of application.

CHRVST - Harvested yield of mature cotton from field that received a chemical treatment.

COTRSLT - Disk file for program output.

CPNEW - Same as PNEW but for a field that received a chemical treatment.

CUBIC - Function to evaluate a cubic polynomial.

CYIELD - Number of bolls per acre that mature on IDATE for a field that received a chemical treatment.

D - Cubic coefficient of cubic polynomial.

DATE - Subroutine to read real time clock and get date program was run.

DIES - Subroutine to compute fraction of pink bollworms from the infestation newly occurring on IDATE that will go into diapause.

DPBW - Number of pink bollworm larvae (per acre) in diapause.

E( ) - Table of error function values.

ERFUN (Z) - Function to calculate error function.

EZM - Two times the area under the normal distribution curve integrated from 0 to ZM.

EZP - Two times the area under the normal distribution curve integrated from 0 to ZP.

F - Fraction of bolls started on JDATE maturing on IDATE. In a later portion of the program, the fraction of bolls started on JDATE are IGRN days old on IDATE.

FDIF - Change of infestation from FYEST on the previous day to FNFST on IDATE.

FDIPAS - Fraction of IDATE's infestation going into diapause.

FGTIM - Subroutine to read real time clock and get time program was run.

FNFST - Ratio of larvae to bolls on IDATE.

FRACT - Fraction of bolls surviving chemical treatment, which were set JDIF days from a chemical treatment.

FYEST - Ratio of larvae to green susceptible bolls for the day prior to the day currently being considered.

GBLS( ) - Array of green bolls present on IDATE. Each element contains the number of bolls per acre of the age in days given by the subscript.

HRDUCT - Percent reduction in harvest due to chemical treatment.

HRVST - Harvested yield of mature cotton in bolls per acre.

ID - Day of month. After a call to SR DIES with MO equal to month, ID is the Julian date. If ID is set equal to the Julian date, and MO to 0, and a call is made to SR DIES, ID becomes day of month again.

IDATE - Julian date. Outer DO loop index.

IGRN - Index for green boll age loops. IGRN is the green boll age in days.

IHR - Hour program was run.

IM - Integerized XM.

IMIN - Minute program was run.

INFEST - Subroutine to compute the ratio of larvae to green bolls for a field that received no chemical treatment.

IOLD - Oldest age at which green bolls cease to be susceptible to pink bollworm.

IOUT - Code for output; 12 for line printer, 2 for disk file called COTRSLT.

IP - Integerized XP.

IP1 - IYNG + 1.

IRUN - Run number index for run loop.

ISEC - Second program was run.

ITITLE( ) - Array of text information to identify particular program run.

IYNG - Youngest age at which green bolls become susceptible to pink bollworm.

IYYEST - Youngest susceptible age, in days, of green bolls for the day prior to the day currently being considered.

I0-I10 - Scaled and integerized output variables.

JDATE - Inner loop Julian date. Inner loop is used to compute the contribution of all the days prior to IDATE to the number of mature and green bolls present on IDATE.

JDIF - Difference between IDATE and day of chemical treatment application. Later in program, it is the difference between IDATE and maturity date, and, later yet, the difference between IDATE and susceptibility dates.

KCHEM - Date of chemical treatment.

KCSTOR( ) - Array of Julian dates that the chemical treatment is to be applied.

KFLWR - Earliest day in year to expect flowering and, therefore, the date to start IDATE loop.

KHRVST - Date of final harvest or termination date for running the program.

LPT - Line printer.

MO - Month of year or when set equal to 0 is code for SR DIES to compute day and month from Julian date.

NAVDA - Integerized AVDA.

NDATE(3) - Array having the day, month, year program was run.

NRUNS - Number of runs with the same set of subroutines and various chemical treatment dates.

PORTN - Ratio of new infestation with no chemical treatment to the total number of green bolls for no chemical treatment.

PNEW - Amount of new infestation, in larvae per acre, occurring on IDATE for a field with no chemical treatment.
PRDUCT - Percent reduction in diapaused pink bollworms due to chemical treatment.
PVBVD - Number of pink bollworms per boll per IGRN day's age.
SIGMA - Standard deviation for normal distribution of maturation rate.
TCGBLS - Same as TGBLS but for a field that received a chemical treatment.
TGBLS - Total number of green bolls per acre of all ages present in field on IDATE.
XM - Lower integration limit equivalent of XP.
XP - Scaled ZP so that the integer portion of XP will be the subscript for finding the correct error function value in E( ) that corresponds to ZP.
YIELD - Number of bolls per acre that mature on the Julian date given by IDATE.
Z - Scaled variable for error function argument.
ZM - Similar to ZP, but represents the lower integration limits or the beginning of the JDATE day.
ZP - Normalized Z variable for axis of normal distribution curve. It is the upper integration limit representing the end of the JDATE day.

Flow Diagrams

Figure 12 (pp. 21-32) consists of several pages of flow diagrams for the main program, each page being a small portion of a larger picture. To aid in seeing the larger picture of computational sequence for the whole program, photocopy the pages and lay them end to end so that the circles with 1, 2, 3, 4, 5, 7, 8, 12, 13, 14, and 15 coincide. Then draw lines to join the other circles with the same number. The flow diagram follows the program almost exactly line by line.

FORTRAN Program

The computer listing of the cotton yield-pink bollworm model is given in figure 13 (pp. 33-42). The program is written in Data General Corporation FORTRAN, but the changes needed to run on other computers are small. One such change that probably will be necessary is to eliminate the five lines that get and write the date and time of the computer run. Another possible change is needed for computer systems that do not have the ACCEPT and TYPE statements for inputting and outputting data from a keyboard terminal. For these systems, the ACCEPT statement will need to be changed to the appropriate READ statements, and the TYPE statements can be eliminated. The first ACCEPT statement requests a value for IOUT, the output device code. Other users should set the value of IOUT to the code for their own line printer, disk file, or other output device. Other deviations from standard FORTRAN, which require changing, are unlikely.

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.

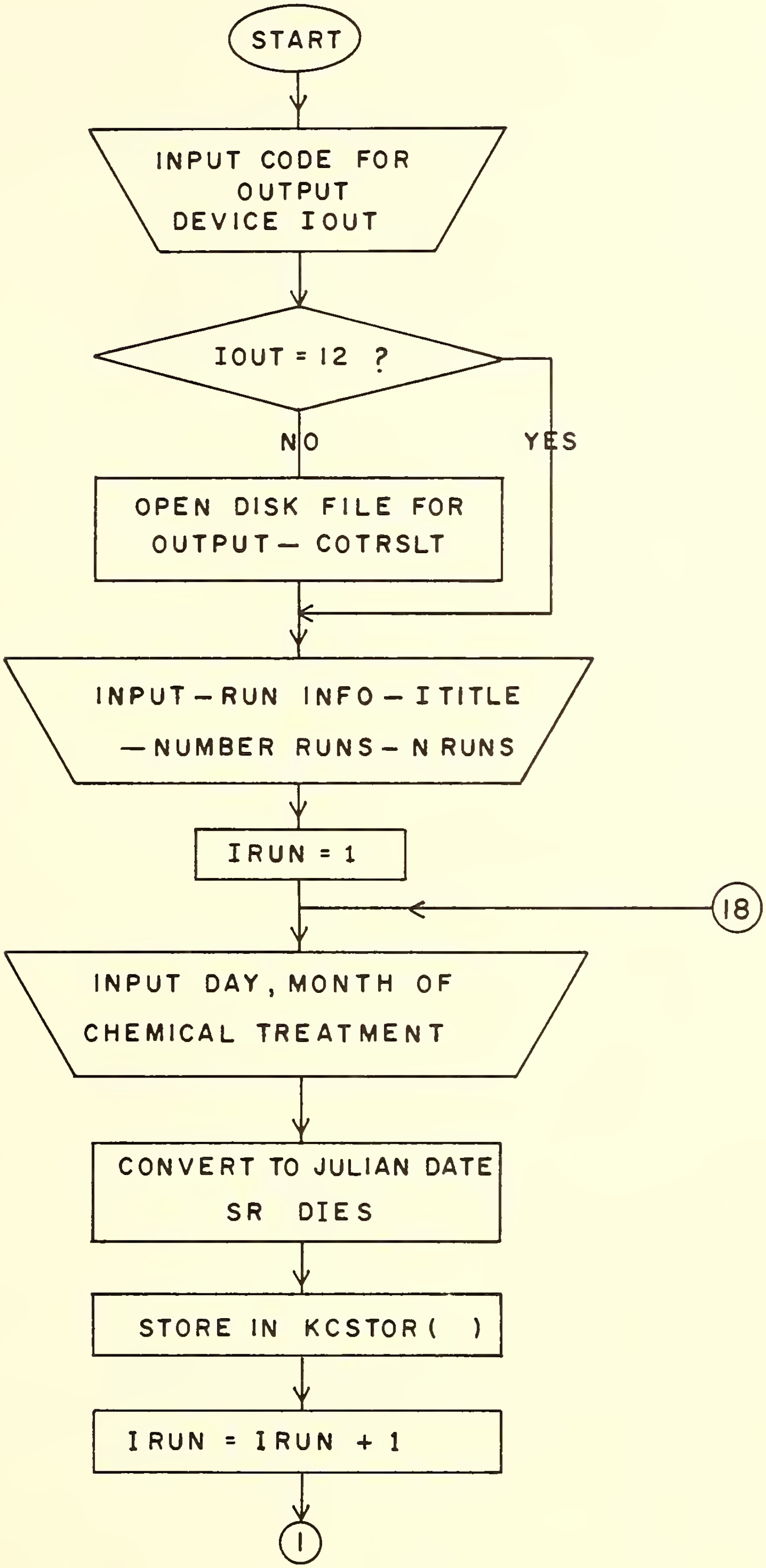

START
INPUT CODE FOR OUTPUT DEVICE IOUT
IOUT = 12 ?
NO
YES
OPEN DISK FILE FOR OUTPUT — COTRSLT
INPUT — RUN INFO — ITITLE
— NUMBER RUNS — NRUNS
IRUN = 1
18
INPUT DAY, MONTH OF CHEMICAL TREATMENT
CONVERT TO JULIAN DATE
SR DIES
STORE IN KCSTOR( )
IRUN = IRUN + 1
1

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

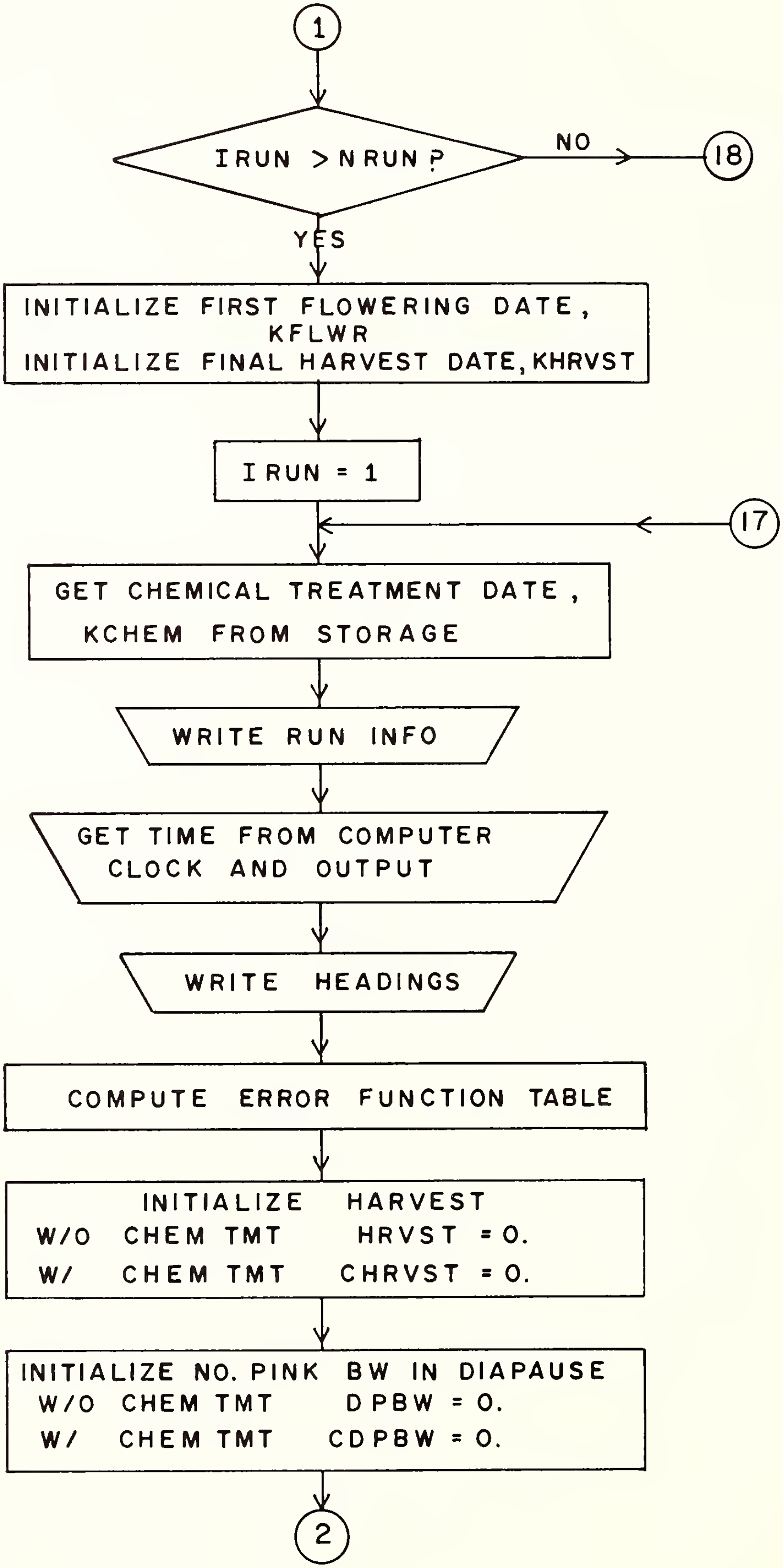

1
IRUN > NRUN ?
NO
18
YES
INITIALIZE FIRST FLOWERING DATE, KFLWR
INITIALIZE FINAL HARVEST DATE, KHRVST
IRUN = 1
17
GET CHEMICAL TREATMENT DATE, KCHEM FROM STORAGE
WRITE RUN INFO
GET TIME FROM COMPUTER CLOCK AND OUTPUT
WRITE HEADINGS
COMPUTE ERROR FUNCTION TABLE
INITIALIZE HARVEST
W/O CHEM TMT HRVST = 0.
W/ CHEM TMT CHRVST = 0.
INITIALIZE NO. PINK BW IN DIAPAUSE
W/O CHEM TMT DPBW = 0.
W/ CHEM TMT CDPBW = 0.
2

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

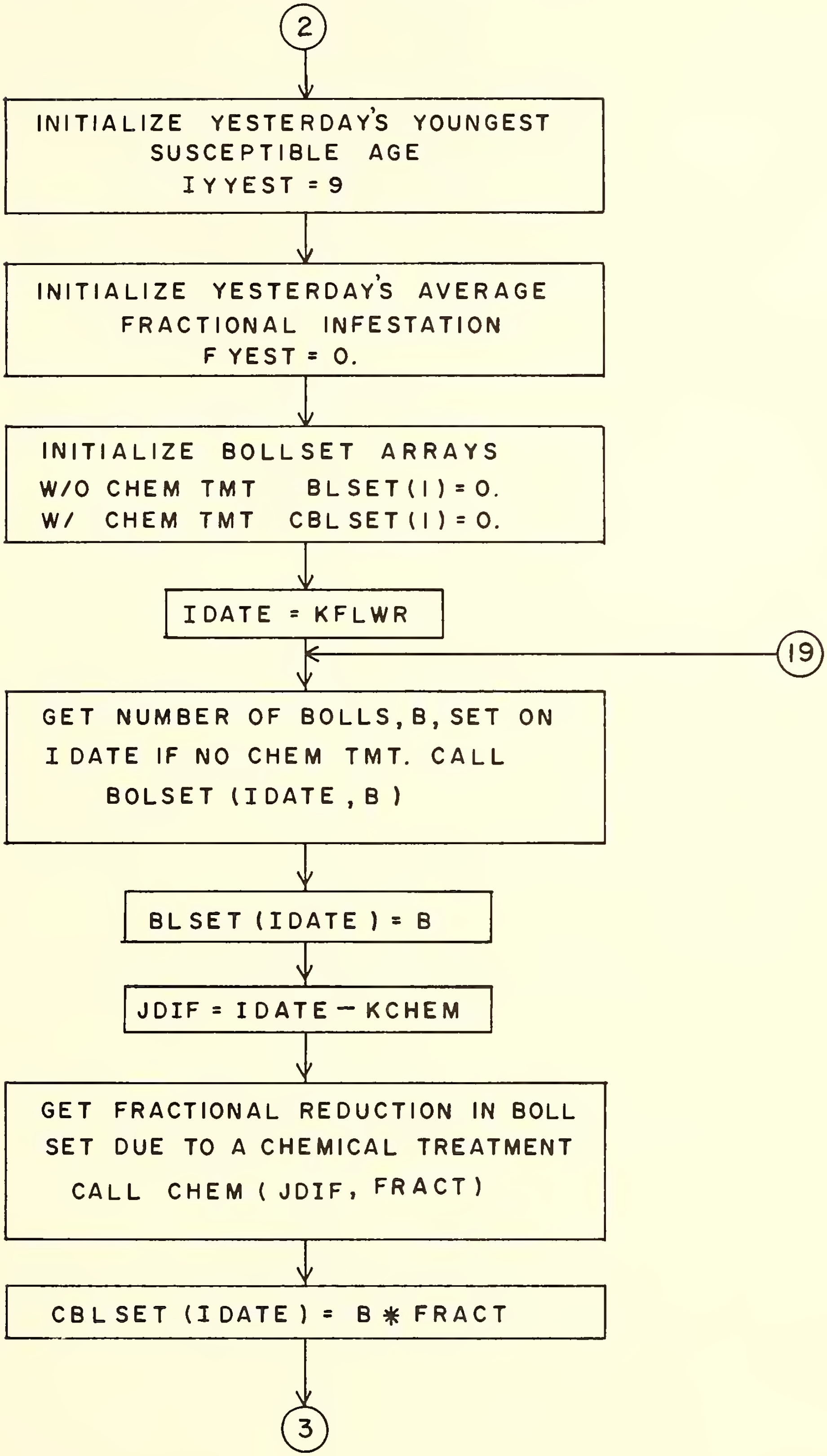

2
INITIALIZE YESTERDAY'S YOUNGEST SUSCEPTIBLE AGE
IYYEST = 9
INITIALIZE YESTERDAY'S AVERAGE FRACTIONAL INFESTATION
F YEST = 0.
INITIALIZE BOLLSET ARRAYS
W/O CHEM TMT BLSET(I) = 0.
W/ CHEM TMT CBLSET(I) = 0.
IDATE = KFLWR
19
GET NUMBER OF BOLLS, B, SET ON IDATE IF NO CHEM TMT. CALL BOLSET (IDATE, B)
BLSET (IDATE) = B
JDIF = IDATE — KCHEM
GET FRACTIONAL REDUCTION IN BOLL SET DUE TO A CHEMICAL TREATMENT
CALL CHEM (JDIF, FRACT)
CBLSET (IDATE) = B * FRACT
3

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

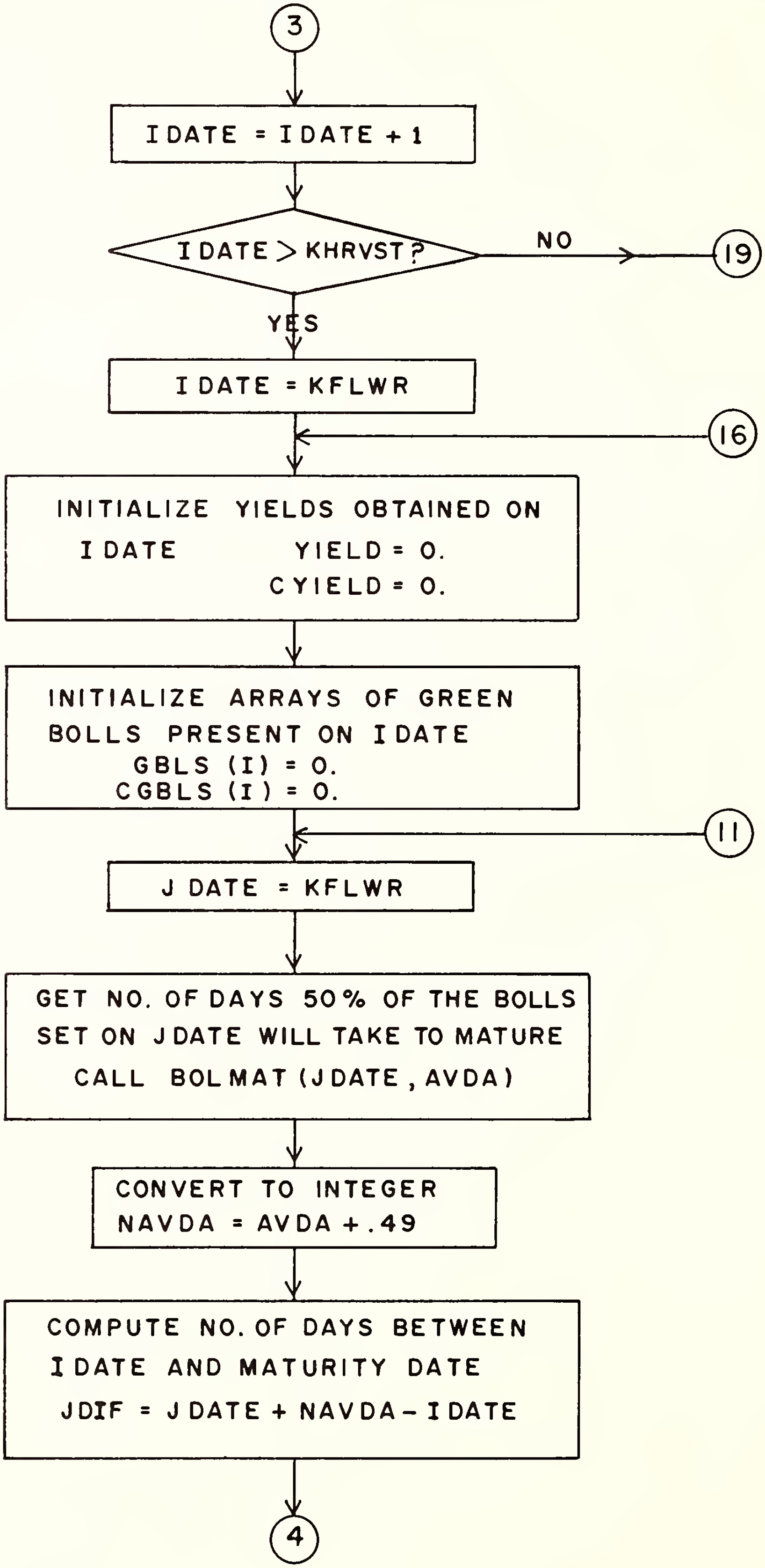

3
IDATE = IDATE + 1
IDATE > KHRVST ?
NO
19
YES
IDATE = KFLWR
16
INITIALIZE YIELDS OBTAINED ON IDATE
YIELD = 0.
CYIELD = 0.
INITIALIZE ARRAYS OF GREEN BOLLS PRESENT ON IDATE
GBLS (I) = 0.
CGBLS (I) = 0.
11
J DATE = KFLWR
GET NO. OF DAYS 50% OF THE BOLLS SET ON JDATE WILL TAKE TO MATURE
CALL BOLMAT (JDATE, AVDA)
CONVERT TO INTEGER
NAVDA = AVDA + .49
COMPUTE NO. OF DAYS BETWEEN IDATE AND MATURITY DATE
JDIF = JDATE + NAVDA - IDATE
4

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

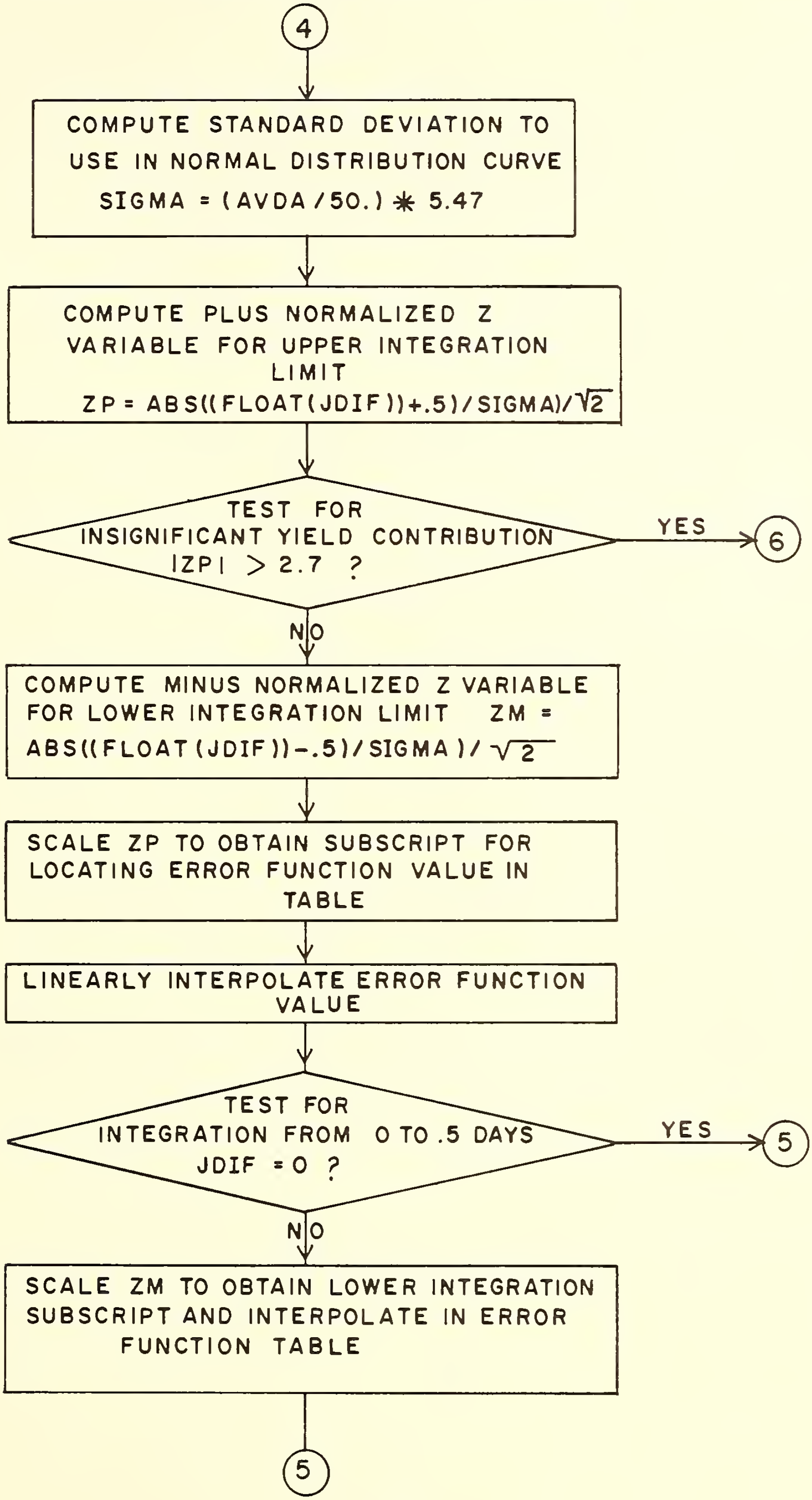
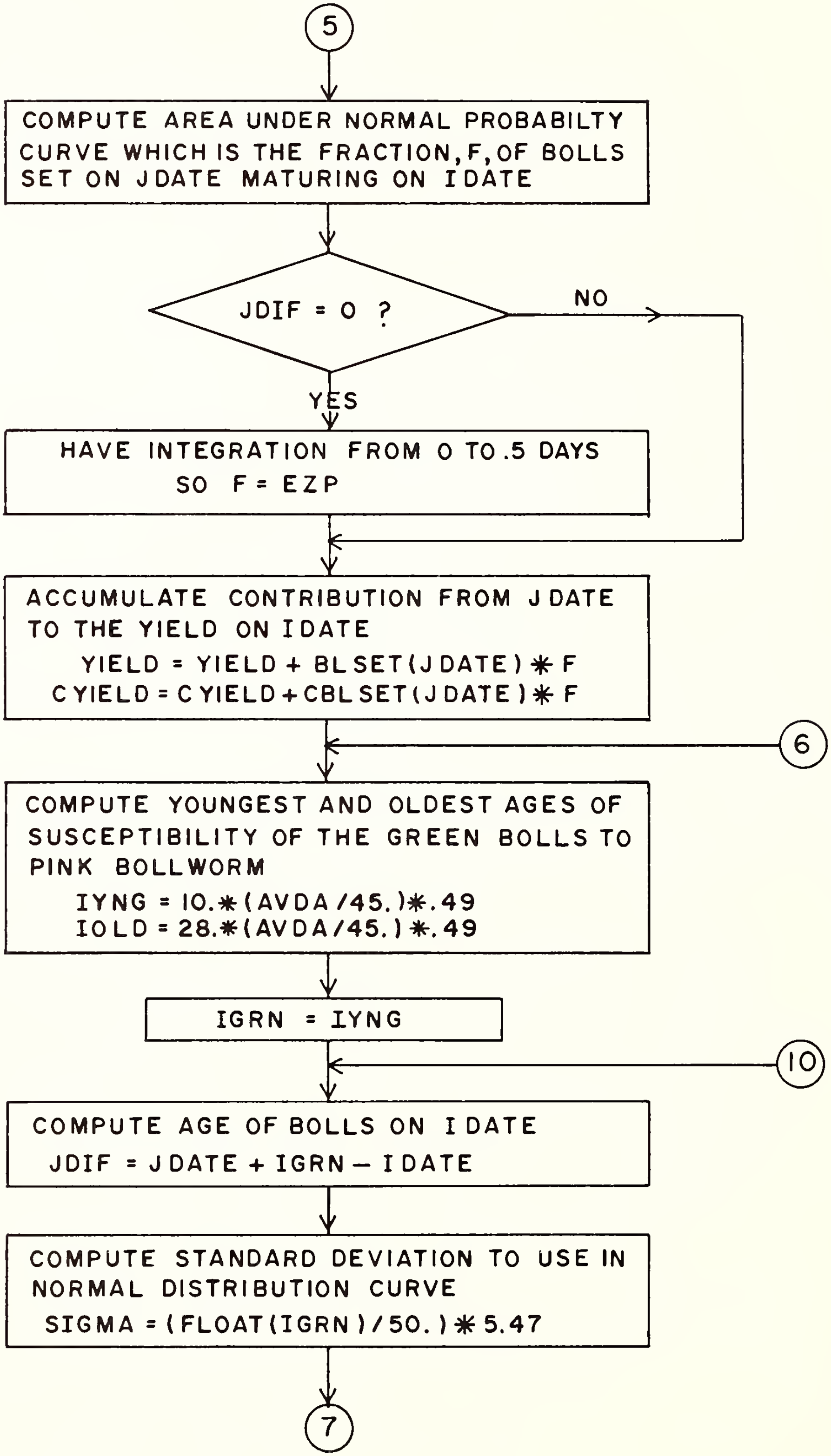

4
COMPUTE STANDARD DEVIATION TO USE IN NORMAL DISTRIBUTION CURVE
SIGMA = (AVDA/50.) * 5.47
COMPUTE PLUS NORMALIZED Z VARIABLE FOR UPPER INTEGRATION LIMIT
ZP = ABS((FLOAT(JDIF))+.5)/SIGMA)/√2
TEST FOR INSIGNIFICANT YIELD CONTRIBUTION
\|ZP\| > 2.7 ?
YES
6
NO
COMPUTE MINUS NORMALIZED Z VARIABLE FOR LOWER INTEGRATION LIMIT ZM =
ABS((FLOAT(JDIF))-.5)/SIGMA)/√2
SCALE ZP TO OBTAIN SUBSCRIPT FOR LOCATING ERROR FUNCTION VALUE IN TABLE
LINEARLY INTERPOLATE ERROR FUNCTION VALUE
TEST FOR INTEGRATION FROM 0 TO .5 DAYS
JDIF = 0 ?
YES
5
NO
SCALE ZM TO OBTAIN LOWER INTEGRATION SUBSCRIPT AND INTERPOLATE IN ERROR FUNCTION TABLE
5

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*



COMPUTE AREA UNDER NORMAL PROBABILTY CURVE WHICH IS THE FRACTION, F, OF BOLLS SET ON JDATE MATURING ON IDATE

JDIF = 0 ?

HAVE INTEGRATION FROM 0 TO .5 DAYS SO F = EZP

ACCUMULATE CONTRIBUTION FROM JDATE TO THE YIELD ON IDATE

```
YIELD = YIELD + BLSET(JDATE)*F
CYIELD = CYIELD+CBLSET(JDATE)*F
```

COMPUTE YOUNGEST AND OLDEST AGES OF SUSCEPTIBILITY OF THE GREEN BOLLS TO PINK BOLLWORM

```
IYNG = 10.*(AVDA/45.)*.49
IOLD = 28.*(AVDA/45.)*.49
```

```
IGRN = IYNG
```

COMPUTE AGE OF BOLLS ON IDATE

```
JDIF = JDATE + IGRN - IDATE
```

COMPUTE STANDARD DEVIATION TO USE IN NORMAL DISTRIBUTION CURVE

```
SIGMA = (FLOAT(IGRN)/50.)*5.47
```

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

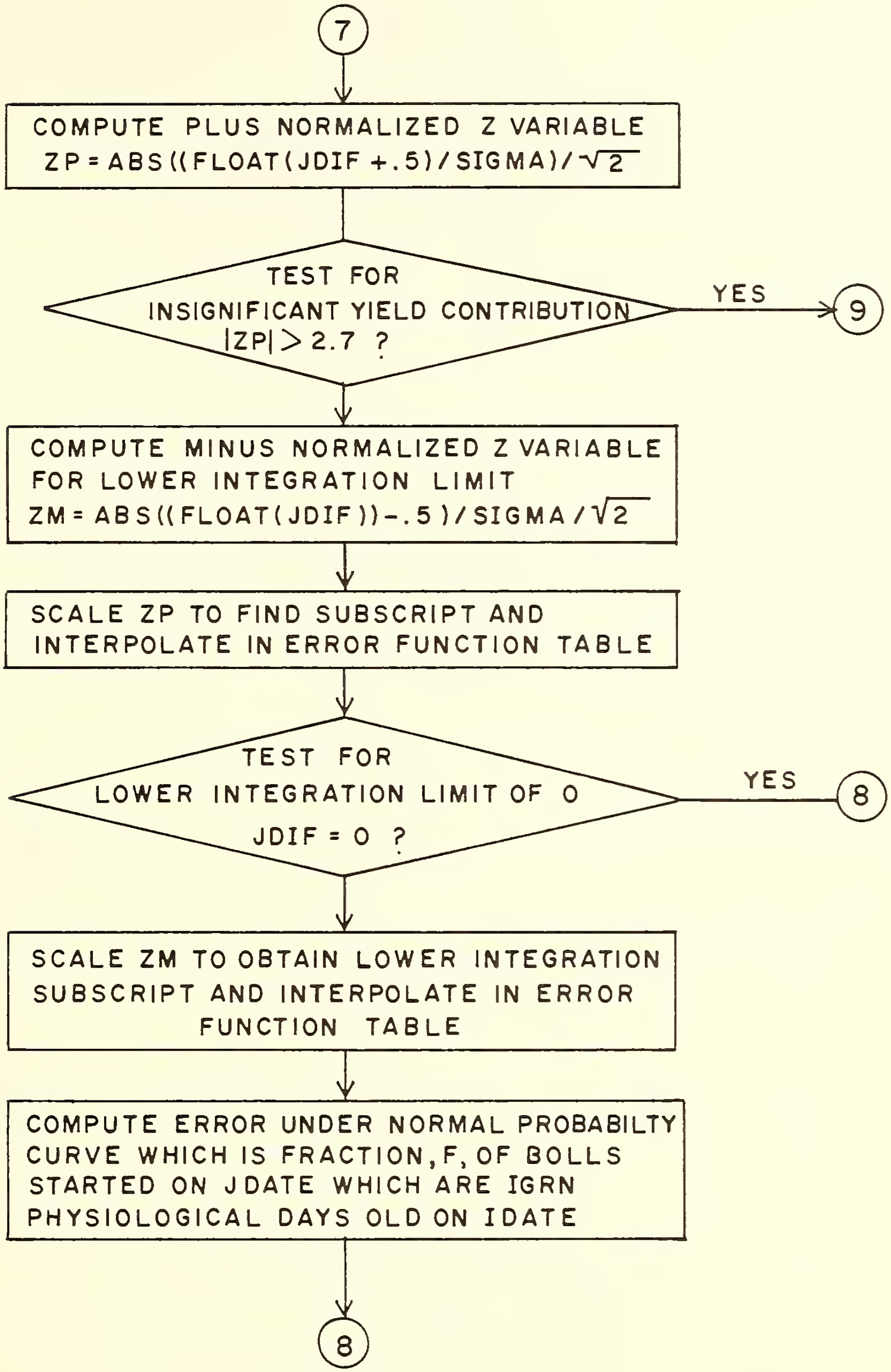

7
COMPUTE PLUS NORMALIZED Z VARIABLE
ZP = ABS((FLOAT(JDIF +.5)/SIGMA)/√2
TEST FOR
INSIGNIFICANT YIELD CONTRIBUTION
|ZP| > 2.7 ?
YES
9
COMPUTE MINUS NORMALIZED Z VARIABLE
FOR LOWER INTEGRATION LIMIT
ZM = ABS((FLOAT(JDIF))-.5)/SIGMA/√2
SCALE ZP TO FIND SUBSCRIPT AND
INTERPOLATE IN ERROR FUNCTION TABLE
TEST FOR
LOWER INTEGRATION LIMIT OF 0
JDIF = 0 ?
YES
8
SCALE ZM TO OBTAIN LOWER INTEGRATION
SUBSCRIPT AND INTERPOLATE IN ERROR
FUNCTION TABLE
COMPUTE ERROR UNDER NORMAL PROBABILTY
CURVE WHICH IS FRACTION, F, OF BOLLS
STARTED ON JDATE WHICH ARE IGRN
PHYSIOLOGICAL DAYS OLD ON IDATE
8

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

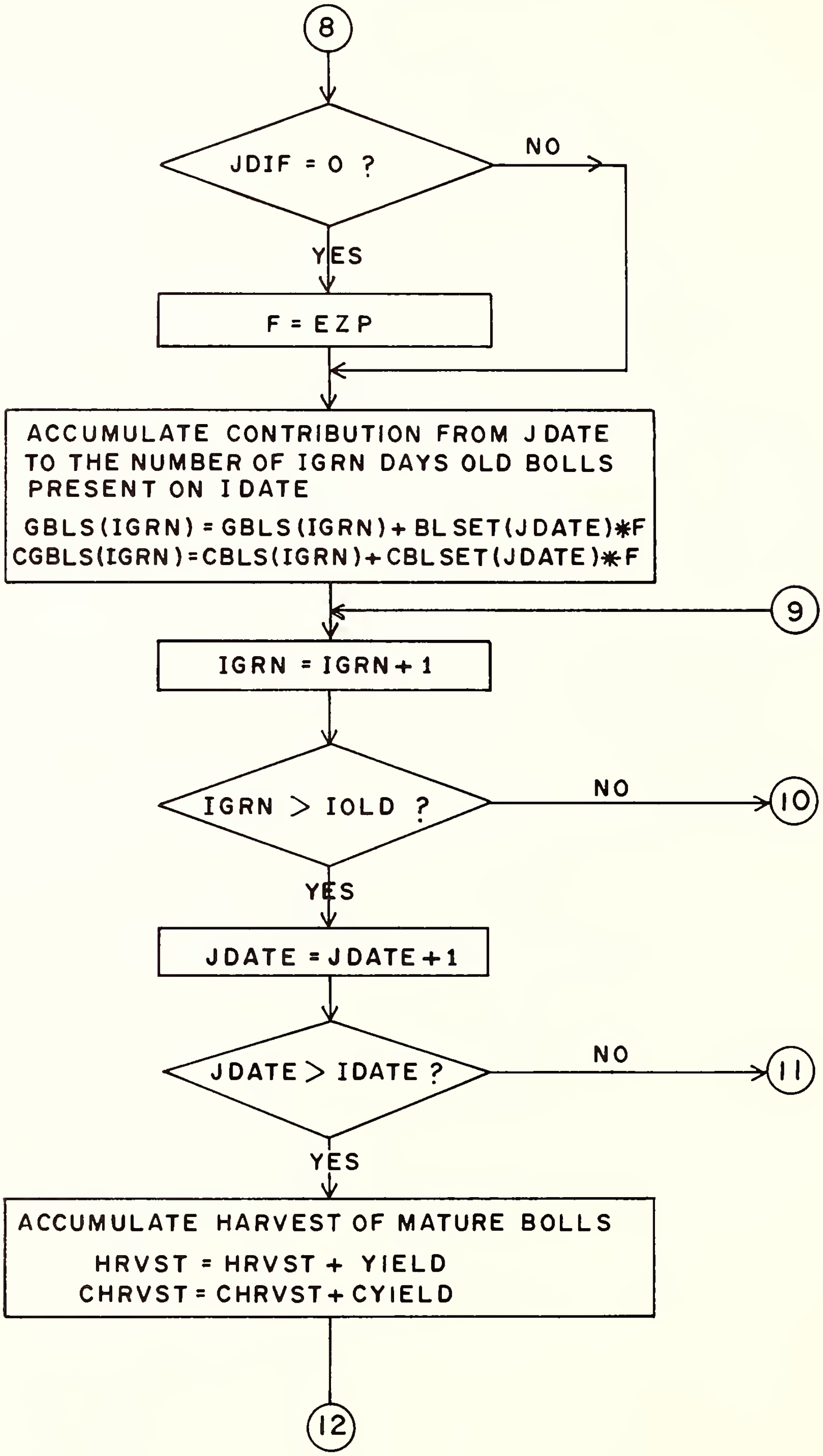

8
JDIF = 0 ?
NO
YES
F = EZP
ACCUMULATE CONTRIBUTION FROM JDATE TO THE NUMBER OF IGRN DAYS OLD BOLLS PRESENT ON IDATE
GBLS(IGRN) = GBLS(IGRN) + BLSET(JDATE)*F
CGBLS(IGRN) = CBLS(IGRN) + CBLSET(JDATE)*F
9
IGRN = IGRN + 1
IGRN > IOLD ?
NO
10
YES
JDATE = JDATE + 1
JDATE > IDATE ?
NO
11
YES
ACCUMULATE HARVEST OF MATURE BOLLS
HRVST = HRVST + YIELD
CHRVST = CHRVST + CYIELD
12

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

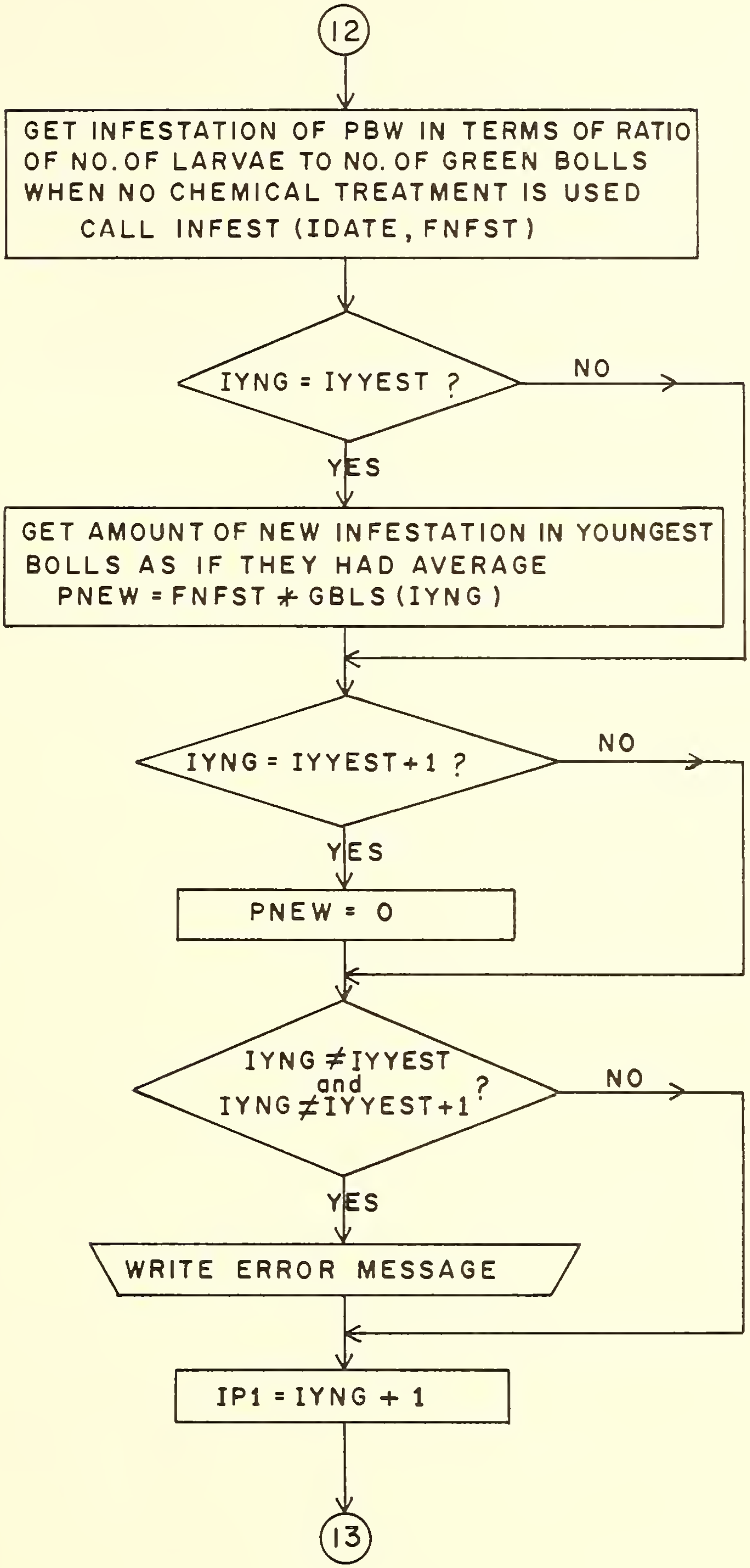

12
GET INFESTATION OF PBW IN TERMS OF RATIO OF NO. OF LARVAE TO NO. OF GREEN BOLLS WHEN NO CHEMICAL TREATMENT IS USED
CALL INFEST (IDATE, FNFST)
IYNG = IYYEST ?
NO
YES
GET AMOUNT OF NEW INFESTATION IN YOUNGEST BOLLS AS IF THEY HAD AVERAGE
PNEW = FNFST * GBLS (IYNG)
IYNG = IYYEST+1 ?
NO
YES
PNEW = 0
IYNG ≠ IYYEST and IYNG ≠ IYYEST+1 ?
NO
YES
WRITE ERROR MESSAGE
IP1 = IYNG + 1
13

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

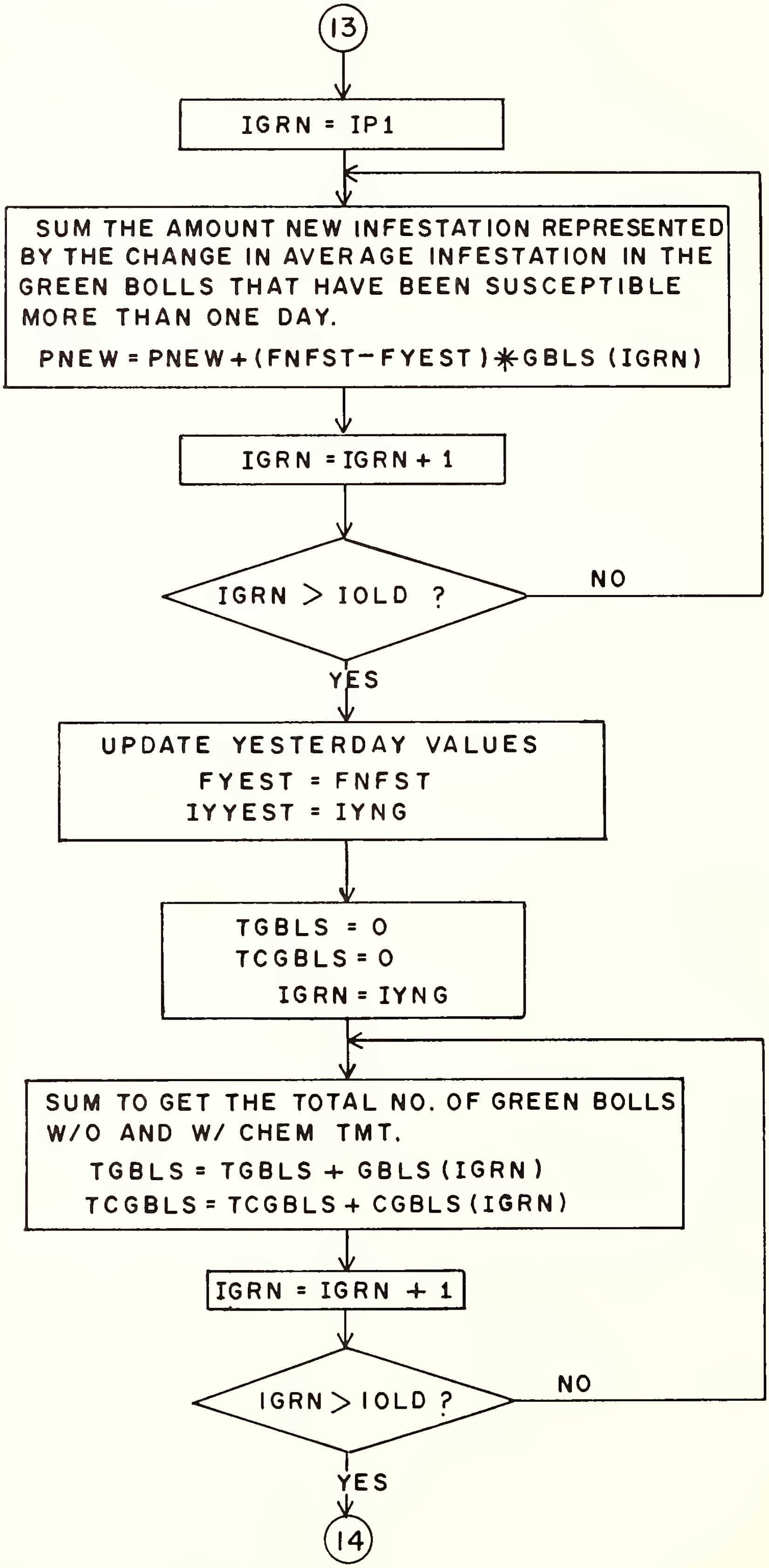

13
IGRN = IP1
SUM THE AMOUNT NEW INFESTATION REPRESENTED BY THE CHANGE IN AVERAGE INFESTATION IN THE GREEN BOLLS THAT HAVE BEEN SUSCEPTIBLE MORE THAN ONE DAY.
PNEW = PNEW + (FNFST − FYEST) * GBLS (IGRN)
IGRN = IGRN + 1
IGRN > IOLD ?
NO
YES
UPDATE YESTERDAY VALUES
FYEST = FNFST
IYYEST = IYNG
TGBLS = 0
TCGBLS = 0
IGRN = IYNG
SUM TO GET THE TOTAL NO. OF GREEN BOLLS W/O AND W/ CHEM TMT.
TGBLS = TGBLS + GBLS (IGRN)
TCGBLS = TCGBLS + CGBLS (IGRN)
IGRN = IGRN + 1
IGRN > IOLD ?
NO
YES
14

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

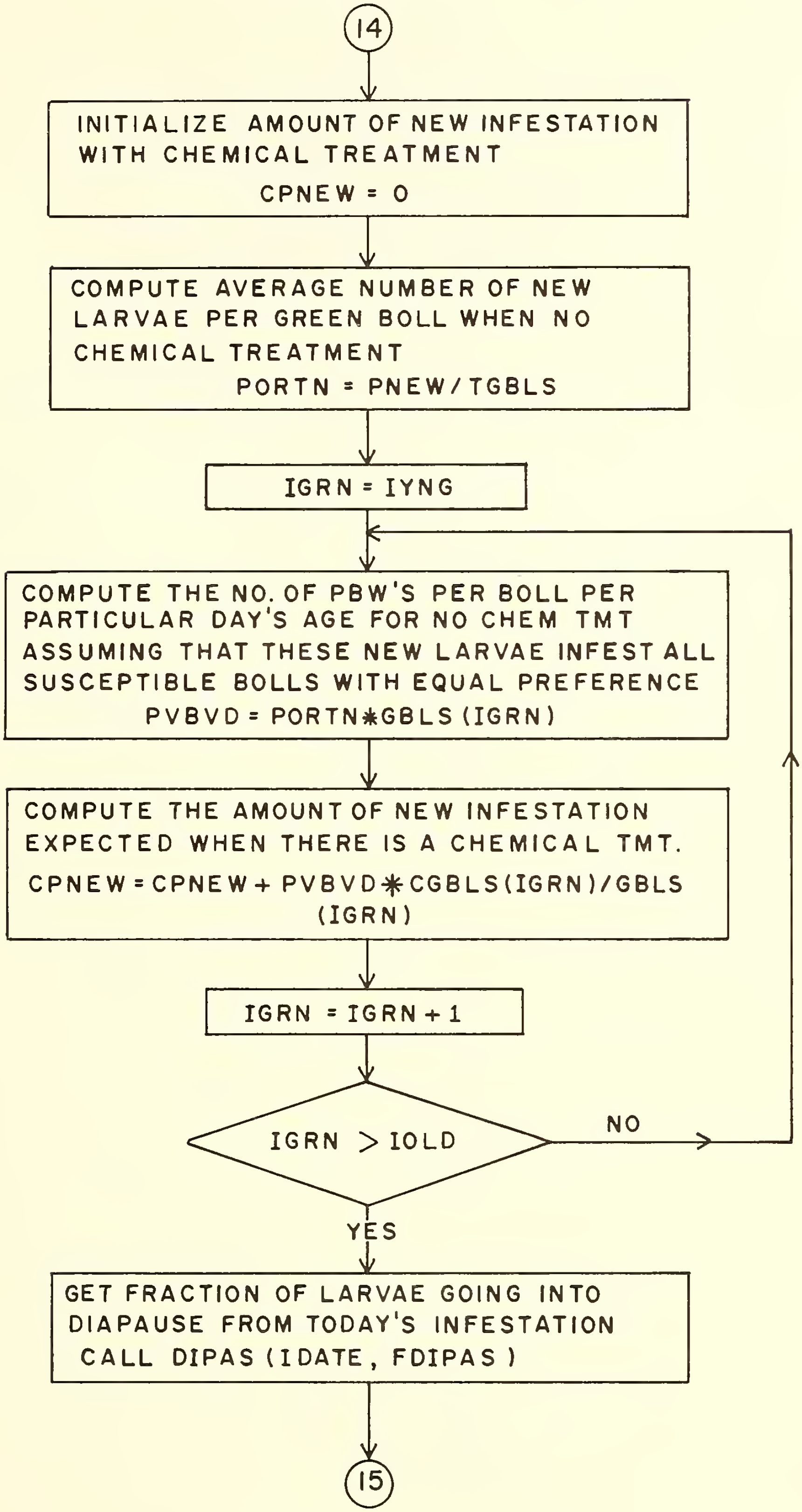

14
INITIALIZE AMOUNT OF NEW INFESTATION WITH CHEMICAL TREATMENT
CPNEW = 0
COMPUTE AVERAGE NUMBER OF NEW LARVAE PER GREEN BOLL WHEN NO CHEMICAL TREATMENT
PORTN = PNEW/TGBLS
IGRN = IYNG
COMPUTE THE NO. OF PBW'S PER BOLL PER PARTICULAR DAY'S AGE FOR NO CHEM TMT ASSUMING THAT THESE NEW LARVAE INFEST ALL SUSCEPTIBLE BOLLS WITH EQUAL PREFERENCE
PVBVD = PORTN*GBLS (IGRN)
COMPUTE THE AMOUNT OF NEW INFESTATION EXPECTED WHEN THERE IS A CHEMICAL TMT.
CPNEW = CPNEW + PVBVD*CGBLS(IGRN)/GBLS (IGRN)
IGRN = IGRN + 1
IGRN > IOLD
NO
YES
GET FRACTION OF LARVAE GOING INTO DIAPAUSE FROM TODAY'S INFESTATION
CALL DIPAS (IDATE, FDIPAS)
15

Figure 12.--Flow diagram for the main program of the cotton yield-pink bollworm model.--*Continued*

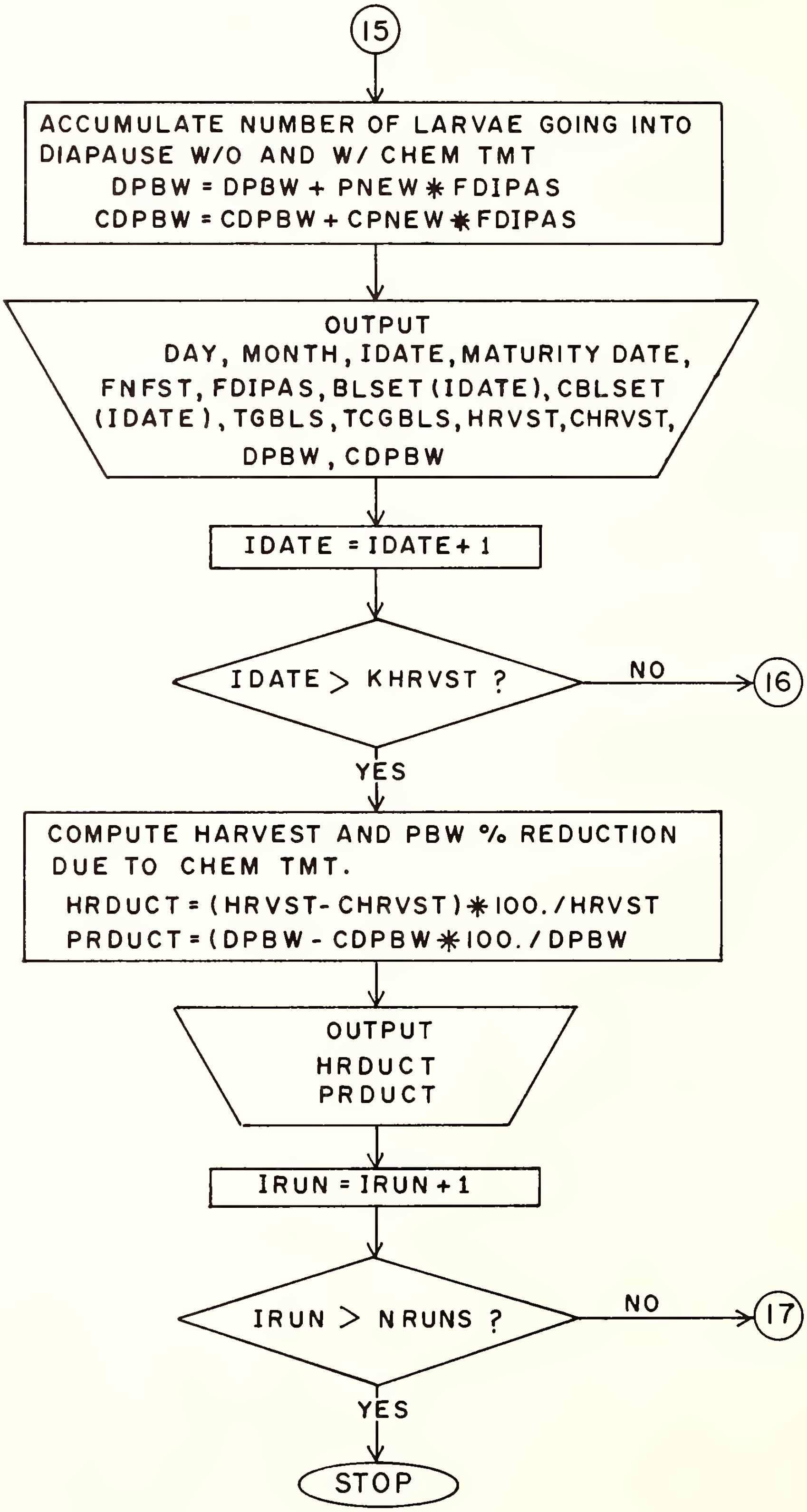

15
ACCUMULATE NUMBER OF LARVAE GOING INTO DIAPAUSE W/O AND W/ CHEM TMT
DPBW = DPBW + PNEW ✱ FDIPAS
CDPBW = CDPBW + CPNEW ✱ FDIPAS
OUTPUT
DAY, MONTH, IDATE, MATURITY DATE, FNFST, FDIPAS, BLSET (IDATE), CBLSET (IDATE), TGBLS, TCGBLS, HRVST, CHRVST, DPBW, CDPBW
IDATE = IDATE + 1
IDATE > KHRVST ?
NO
16
YES
COMPUTE HARVEST AND PBW % REDUCTION DUE TO CHEM TMT.
HRDUCT = (HRVST - CHRVST) ✱ 100. / HRVST
PRDUCT = (DPBW - CDPBW ✱ 100. / DPBW
OUTPUT
HRDUCT
PRDUCT
IRUN = IRUN + 1
IRUN > NRUNS ?
NO
17
YES
STOP

Figure 13a.--Computer listing of the main program of the cotton yield-pink bollworm model.

```
C
C           COTTON YIELD - PINK BOLLWORM MODEL
C
C           PROGRAM TO COMPUTE THE COTTON YIELD AND DIAPAUSING
C     PINK BOLLWORM POPULATIONS FOR FIELDS THAT HAVE AND HAVE NOT
C     BEEN TREATED WITH CHEMICALS TO TERMINATE LATE SEASON BOLL SET.
C
C           PROGRAMMED BY B. A  KIMBALL (MAY, 1976)
C           U. S. WATER CONSERVATION LABORATORY
C           4331 E. BROADWAY
C           PHOENIX AZ85040
C
C           FOR DATA GENERAL CORPORATION NOVA 800 JUMBO
C     MINICOMPUTER WITH 32K OF MEMORY, CRT TERMINAL, LINE PRINTER,
C     AND DISK.
C
      DIMENSION BLSET(500),CBLSET(500),GBLS(100),CGBLS(100)
      DIMENSION ITITLE(40),NDATE(3),E(280),KCSTOR(20)
      TYPE "       COTTON YIELD - PINK BOLLWORM MODEL"
      ACCEPT"OUTPUT TO LPT(12) OR COTRSLT(2) ? ",IOUT
      IF(IOUT.NE.12) CALL OPEN (IOUT,"COTRSLT")
      TYPE "RUN INFORMATION ? "
      READ(11,2) ITITLE(1)
  2   FORMAT(S72)
      ACCEPT"NO. OF RUNS ", NRUNS
      DO 23 IRUN=1,NRUNS
      ACCEPT"CHEMICAL TREATMENT DATE    (D,M) ",ID,MO
      CALL DIES(ID,MO,75)
      KCSTOR(IRUN)=ID
 23   CONTINUE
C     FIRST FLOWERING DATE
      KFLWR=154
C     FINAL HARVEST DATE
      KHRVST=334
C
C     START RUN LOOP
      DO 9999 IRUN=1,NRUNS
      KCHEM=KCSTOR(IRUN)
C
C     WRITE RUN INFORMATION
      WRITE(IOUT,15) ITITLE(1)
 15   FORMAT(1X,S72)
      WRITE(IOUT,16) KCHEM
 16   FORMAT(" DATE OF CHEMICAL TREATMENT = ",I4/"   ")
C     GET AND WRITE RUN TIME
      CALL FGTIM(IHR,IMIN,ISEC)
      CALL DATE(NDATE,IER)
      WRITE(IOUT,13) NDATE(2),NDATE(1),NDATE(3),IHR,IMIN,ISEC
 13   FORMAT(" RUN ON ",3I3,"  AT ",3I3/"   ")
C     WRITE HEADINGS
      WRITE(IOUT,14)
 14   FORMAT(28X,"BOLL SET  GREEN BOLLS    HARVEST  DIAPAUSE PBW"/
     1   12X,"MATR",1X,"IPS DIPS",4("    CK    TMT  ")/
     2   " DA MO DATE DATE ",2(" %  "),5X,"/A/DA",
```

Figure 13b.--Computer listing of the main program of the cotton yield-pink bollworm model.--*Continued*

```
     3     4X,8(" -"),"/.01A",8(" -"))
C
C     SET UP ERROR FUNCTION TABLE
      DO 30 I=1,280
      Z=FLOAT(I-1)/100.
      E(I)=ERFUN(Z)
   30 CONTINUE
C
C     INITIALIZE HARVEST AND NUMBER OF PINK BOLLWORMS IN DIAPAUSE
      HRVST=0.
      CHRVST=0.
      DPBW=0.
      CDPBW=0.
C
C     INITIALIZE YESTERDAY'S YOUNGEST SUSEPTIBLE AGE AND YESTERDAY'S
C     AVERAGE FRACTIONAL INFESTATION
      IYYEST=9.
      FYEST=0.
C
C     INITIALIZE BOLLSET ARRAYS
      DO 1 I=1,KHRVST
      BLSET(I)=0.
      CBLSET(I)=0.
    1 CONTINUE
C
C     COMPUTE BOLL SET WITHOUT AND WITH CHEMICAL TREATMENT.
      DO 3 IDATE=KFLWR,KHRVST
      CALL BOLSET(IDATE,B)
      BLSET(IDATE)=B
      JDIF=IDATE-KCHEM
      CALL CHEM(JDIF,FRACT)
      CBLSET(IDATE)=B*FRACT
    3 CONTINUE
C
C     START OUTER LOOP
      DO 999 IDATE=KFLWR,KHRVST
C
C     INITIALIZE YIELDS OBTAINED ON IDATE
      YIELD=0.
      CYIELD=0.
C
C     INITIALIZE ARRAYS OF GREEN BOLLS PRESENT ON IDATE
      DO 4 I=1,100
      GBLS(I)=0.
      CGBLS(I)=0.
    4 CONTINUE
C
C     START SECONDARY LOOP TO CONTRIBUTION FROM ALL PREVIOUS DATES YIELD
C     AND GREEN BOLL ARRAY
      DO 998 JDATE=KFLWR,IDATE
C
C     GET NO. OF DAYS THE BOLLS SET ON JDATE WILL TAKE TO MATURE.
      CALL BOLMAT(JDATE,AVDA)
      NAVDA=AVDA+.49
```

Figure 13c.--Computer listing of the main program of the cotton yield-pink bollworm model.--*Continued*

```
C     GET CONTRIBUTION FROM JDATE TO THE YIELD ON IDATE
C     COMPUTE NO. OF DAYS FROM MATURITY DATE TO IDATE
      JDIF=JDATE+NAVDA-IDATE
C
C     COMPUTE STANDARD DEVIATION TO USE IN NORMAL DISTRIBUTION
C     CURVE AND THE NORMALIZED VARIABLE, Z.
      SIGMA=(AVDA/50.)*5.47
      ZP=((ABS(FLOAT(JDIF))+.5)/SIGMA)/1.41421
      IF(ABS(ZP).GT.2.7) GOTO 20
      ZM=((ABS(FLOAT(JDIF))-.5)/SIGMA)/1.41421
C
C     GET FRACTION OF THE BOLLS STARTED ON JDATE MATURING ON IDATE
      XP=ZP*100.  + 1.
      IP=XP
      EZP=E(IP)+(XP-FLOAT(IP))*(E(IP+1)-E(IP))
      IF(JDIF.EQ.0) GOTO 22
      XM=ZM*100.  + 1
      IM=XM
      EZM=E(IM)+(XM-FLOAT(IM))*(E(IM+1)-E(IM))
      F=(EZP-EZM)/2.
   22 IF(JDIF.EQ.0) F=EZP
      YIELD=YIELD+BLSET(JDATE)*F
      CYIELD=CYIELD+CBLSET(JDATE)*F
C
C
C     GET CONTRIBUTION FROM JDATE TO THE NUMBER OF GREEN BOLLS FOR
C     EACH DAY OF AGE THAT THE BOLLS ARE SUSEPTIBLE TO PINK BOLLWORM
C     FIRST NORMALIZE FIRST AND OLDEST SUSEPTIBILITY AGES FOR THE
C     CHANGE IN MATURATION AGE DURING SEASON
   20 IYNG=10.*(AVDA/45.)+.49
      IOLD=28.*(AVDA/45.) + .49
      DO 997 IGRN=IYNG,IOLD
C
C     GET CONTRIBUTION FROM JDATE TO THE NUMBER OF IGRN DAYS OLD BOLLS
C     PRESENT ON IDATE
      JDIF=JDATE+IGRN-IDATE
C
C     COMPUTE STANDARD DEVIATION TO USE IN NORMAL DISTRIBUTION CURVE
C     AND NORMALIZED VARIABLE, Z
      SIGMA=(FLOAT(IGRN)/50.)*5.47
      ZP=((ABS(FLOAT(JDIF))+.5)/SIGMA)/1.41421
      IF(ABS(ZP).GT. 2.7) GOTO 997
      ZM=((ABS(FLOAT(JDIF))-.5)/SIGMA)/1.41421
C
C     GET FRACTION OF THE BOLLS STARTED ON JDATE WHICH  ARE IGRN
C     DAYS OLD ON IDATE.
      XP=ZP*100.  + 1.
      IP=XP
      EZP=E(IP)+(XP-FLOAT(IP))*(E(IP+1)-E(IP))
      IF(JDIF.EQ.0) GOTO 21
      XM=ZM*100. + 1.
      IM=XM
      EZM=E(IM)+(XM-FLOAT(IM))*(E(IM+1)-E(IM))
```

Figure 13d.--Computer listing of the main program of the cotton yield-pink bollworm model.--*Continued*

```
      F=(EZP-EZM)/2.
   21 IF(JDIF.EQ.0) F=EZP
      GBLS(IGRN)=GBLS(IGRN)+BLSET(JDATE)*F
      CGBLS(IGRN)=CGBLS(IGRN)+CBLSET(JDATE)*F
C
  997 CONTINUE
  998 CONTINUE
C
C     ACCUMULATE HARVEST OF MATURE BOLLS
      HRVST=HRVST+YIELD
      CHRVST=CHRVST+CYIELD
C
C     COMPUTE THE AVERAGE RATIO OF LARVAE PER "10-28" DAY OLD BOLLS UNDER
C     NORMAL CONDITIONS WHEN NO CHEMICAL TREATMENT IS USED.
      CALL INFEST(IDATE,FNFST)
C
C     GET THE AMOUT OF NEW INFESTATION FOR NO CHEM TMT.
      IF(IYNG.EQ.IYYEST) PNEW=FNFST*GBLS(IYNG)
      IF(IYNG.EQ.IYYEST+1) PNEW=0.
      IF(IYNG.NE.IYYEST.AND.IYNG.NE.IYYEST+1) WRITE(IOUT,5) IDATE
    5 FORMAT(" GREEN BOLLS INITIAL DAY OF SUSEPTIBILITY ALIGNMENT ERROR"/
     1" IDATE = ",I5)
      IP1=IYNG+1
      FDIF=FNFST-FYEST
      DO 6 IGRN=IP1,IOLD
      PNEW=PNEW+FDIF*GBLS(IGRN)
    6 CONTINUE
C
C     UPDATE YESTERDAY VALUES
      FYEST=FNFST
      IYYEST=IYNG
C
C     GET THE TOTAL NUMBER OF GREEN BOLLS
      TGBLS=0.
      TCGBLS=0.
      DO 7 IGRN=IYNG,IOLD
      TGBLS=TGBLS+GBLS(IGRN)
      TCGBLS=TCGBLS+CGBLS(IGRN)
    7 CONTINUE
C
C     START LOOP FOR COMPUTING THE INFESTATION WHEN THERE IS A CHEM TMT
      CPNEW=0.
      PORTN=PNEW/TGBLS
      DO 8 IGRN=IYNG,IOLD
C
C     COMPUTE THE NUMBER OF LARVAE PER BOLL PER PARTICULAR DAY'S AGE FOR
C     NO CHEM TMT, ASSUMING THAT THESE NEW LARVAE INFEST ALL SUSEPTIBLE
C     BOLLS WITH EQUAL PREFERENCE.
      PVBVD=PORTN*GBLS(IGRN)
C
C     NOW KNOWING THE LARVAE/BOLL/DAY AGE FOR THE IGRN TH DAY AGE FOR NO
C     CHEM TMT, COMPUTE THE AMOUNT OF NEW INFESTAION EXPECTED WHEN THERE
C     IS A CHEM TMT.
      CPNEW=CPNEW+PVBVD*CGBLS(IGRN)/GBLS(IGRN)
```

Figure 13e.--Computer listing of the main program of the cotton yield-pink bollworm model.--*Continued*

```
    8 CONTINUE
C
C     COMPUTE FRACTION OF LARVAE GOING INTO DIAPAUSE FROM TODAY'S
C     INFESTATION.
      CALL DIPAS(IDATE,FDIPAS)
C
C     ACCUMULATE NUMBER OF LARVAE GOING INTO DIAPAUSE W/O AND W/ CHEM TMT.
      DPBW=DPBW+PNEW*FDIPAS
      CDPBW=CDPBW+CPNEW*FDIPAS
C
C     OUTPUT RESULTS
      IO=NAVDA+IDATE
      I1=FNEST*100.     +.49
      I2=FDIPAS*100.     +.49
      I3=BLSET(IDATE) +.49
      I4=CBLSET(IDATE) +.49
      I5=TGBLS/100.  +.49
      I6=TCGBLS/100.  +.49
      I7=HRVST/100.  +.49
      I8=CHRVST/100.  +.49
      I9=DPBW/100.  +.49
      I10=CDPBW/100.  +.49
      ID=IDATE
      MO=0
      CALL DIES(ID,MO,75)
      WRITE(IOUT,11)ID,MO,IDATE,IO,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
   11 FORMAT(1X,2(I2,","),2(I4,","),2(I3,","),7(I5,","),I5)
C
  999 CONTINUE
C
C     COMPUTE HARVEST AND DIAPAUSED PINK BOLLWORM REDUCTION DUE TO
C     CHEMICAL TREATMENT.
      HRDUCT=(HRVST-CHRVST)*100./HRVST
      PRDUCT=(DPBW-CDPBW)*100./DPBW
      WRITE(IOUT,12) HRDUCT,PRDUCT
   12 FORMAT("   "/" HARVEST REDUCTION        (%) = ",F6.1/
     1         " PINK BOLLWORM REDUCTION (%) = ",F6.1)
      DO 24 I=1,6
   24 WRITE(IOUT,25)
   25 FORMAT("       ")
 9999 CONTINUE
      STOP
      END
```

Figure 13f.--CUBIC function.

```
      FUNCTION CUBIC(A,B,C,D,X)
C
C             CUBIC EVALUATES THE CUBIC POLYNOMIAL
C     CUBIC= A + B*X + C*X**2 + D*X**3
C             GIVEN A,B,C,D, AND X.
C
      CUBIC= A + X*(B + X*(C + X*D))
      RETURN
      END
```

Figure 13g.--ERFUN function.

```
      COMPILER DOUBLE PRECISION
      FUNCTION ERFUN(X)
C
C             FUNCTION ERFUN(X) COMPUTES THE ERROR FUNCTION FOR A GIVEN
C     VALUE OF X FOLLOWING THE SERIES 590. P. 136 IN DWIGHT, B.H.,
C     TABLES OF INTEGRALS AND OTHER MATHEMATICAL DATA, MACMILLAN CO.,
C     N.Y., 1961.
C
C     TEST FOR LARGE X
      ERFUN=-1
      IF(X.LE.-4.) RETURN
      ERFUN=+1
      IF(X.GE.+4.)RETURN
C
C     INITIALIZE SUM,SIGN,NUMERATOR,FACTORIAL
      SUM=1.
      JSIGN=1
      FACT=1.
      XSQ=X*X
      XNUM=1.
C
C     START ITERATION LOOP
      N=0
    1 N=N+1
      FACT=FACT*FLOAT(N)
      DENOM=FACT*FLOAT(2*N+1)
      XNUM=XNUM*XSQ
      JSIGN=JSIGN*(-1)
      TERM=FLOAT(JSIGN)*XNUM/DENOM
      SUM=SUM+TERM
      IF(ABS(TERM).LE.1.E-8) GOTO 2
      GOTO 1
C
C     CONVERGENCE ATTAINED
    2 ERFUN=X*SUM*1.128379
      RETURN
      END
```

Figure 13h.--CHEM subroutine for 2,4-D plus chlorflurenol (fig. 5).

```
C     2,4-D + CHLORFLURENOL
      SUBROUTINE CHEM (JDIF,FRACT)
C
C             SR CHEM COMPUTES THE FRACTIONAL REDUCTION IN BOLL SET,
C     FRACT, AS A FUNCTION OF DAYS FROM TREATMENT, JDIF, FOR
C     COTTON TREATED WITH 2,4-D + CHLORFLURENOL.
C
      X=JDIF
      IF(JDIF.LE.-10) FRACT=100.
      IF(JDIF.GT.-10 .AND. JDIF.LE.23)
     1    FRACT=CUBIC(.445755E3,-.399778E1,.181024,-.405049E-2,X)
      IF(JDIF.GT.23) FRACT=0.
      FRACT=FRACT/100.
      RETURN
      END
```

Figure 13i.--CHEM subroutine for TD-1123 plus chlorflurenol (fig. 6).

```
C     TD1123 + CHLORFLURENOL
      SUBROUTINE CHEM(JDIF,FRACT)
C
C             SR CHEM COMPUTES THE FRACTIONAL REDUCTION IN BOLL SET
C     , FRACT, AS A FUNCTION OF DAYS FROM TREATMENT, JDIF, FOR COTTON
C     TREATED WITH TD1123 + CHLORFLURENOL.
C
      X=JDIF
      IF(JDIF.LE.-10) FRACT=100.
      IF(JDIF.GT.-10 .AND. JDIF.LE.-5)
    1    FRACT=CUBIC(-.947711E2,-.564754E2,-.1099052E2,-.766635,X)
      IF(JDIF.GT.-5 .AND. JDIF.LF.-3)
    2    FRACT=CUBIC(-.155346E1,-.544824,.280892,-.208937E-1,X)
      IF(JDIF.GT.-3) FRACT=0.
      FRACT=FRACT/100.
      RETURN
      END
```

Figure 13j.--BOLSET subroutine for DPL 16 cotton (fig. 1).

```
C     1973 DPL 16 COTTON  PARKER AZ
      SUBROUTINE BOLSET(IDATE,BOLLS)
C
C             THIS SR BOLSET COMPUTES BOLLS, THE NUMBER OF BOLLS
C     SET PER ACRE PER DAY, AS A FUNCTION OF IDATE, THE GIVEN
C     JULIAN DATE THROUGH THE GROWING SEASON FOR DPL 16 COTTON
C     IN 1973 AT PARKER, AZ.
C
      X=IDATE
      IF(IDATE LE.163) BOLLS=0.
      IF(IDATE.GT.163 .AND. IDATE.LE.175)
    1    BOLLS=CUBIC(-.219660E8,.392813E6,-.234316E4,.466268E1,X)
      IF(IDATE.GT.175 .AND. IDATE .LE.183)
    2    BOLLS=CUBIC(.736304E8,-.124598E7,.702139E4,-.131746E2,X)
      IF(IDATE.GT.183 .AND. IDATE.LF 187)
    3    BOLLS=CUBIC(-.112125E9,.179919E7,-.961890E4,.171356E2,X)
      IF(IDATE.GT.187 .AND. IDATE.LF.195)
    4    BOLLS=CUBIC(-.515414E7,.830775E5,-.441827E3,.777208,X)
      IF(IDATE.GT.195 .AND. IDATE.LE 288)
    5    BOLLS=CUBIC(.121532E7,-.149142E5,.606948E2,-.818026E-1,X)
      IF(IDATE.GT.288) BOLLS=0.
      RETURN
      END
```

Figure 13k.--BOLSET subroutine for AZ 64 cotton (fig. 2).

```
C     1975 AZ64 COTTON        CRC PHOENIX
      SUBROUTINE BOLSET(IDATE,BOLLS)
C
C             THIS SR BOLSET COMPUTES BOLLS, THE NUMBER OF BOLLS SET PER
C     ACRE PER DAY, AS A FUNCTION OF IDATE, THE GIVEN JULIAN DATE
C     THROUGH THE GROWING SEASON FOR AZ64 COTTON IN 1975 AT
C     PHOENIX, AZ.
C
      X=IDATE
      IF(IDATE.LE.165) BOLLS =0.
      IF(IDATE.GT.165 .AND. IDATE.LE.190)
     1   BOLLS=CUBIC(.670213E5,-.106911E4,.551010E1,-.904104E-2,X)
      IF(IDATE.GT.190 .AND. IDATE.LE.205)
     2   BOLLS=CUBIC(.278518E6,-.440853E4,.230860E2,-.398760E-1,X)
      IF(IDATE.GT.205 .AND. IDATE.LE.215)
     3   BOLLS=CUBIC(-.505068E7,.735798E5,-.357345E3,.578711,X)
      IF(IDATE.GT.215 .AND. IDATE.LE.230)
     4   BOLLS=CUBIC(.877021E7,-.119270E6,.539630E3,-.811948,X)
      IF(IDATE.GT.230 .AND. IDATE.LE.240)
     5   BOLLS=CUBIC(-.769913E7,.955476E5,-.394358E3,.541659,X)
      IF(IDATE.GT.240 .AND. IDATE.LE.260)
     6   BOLLS=CUBIC(-.226828E7,.276620E5,-.111502E3,.148802,X)
      IF(IDATE.GT.260 .AND. IDATE.LE.300)
     7   BOLLS=CUBIC(.125268E7,-.129645E5,.447539E2,-.515275E-1,X)
      IF(IDATE.GT.300) BOLLS =0.
      RETURN
      END
```

Figure 13l.--INFEST subroutine for no insecticide (fig. 7).

```
C     NO INSECTICIDE TREATMENT
      SUBROUTINE INFEST(IDATE,FNFST)
C
C             THIS SR INFEST COMPUTES THE FRACTION OF GREEN BOLLS INFESTED
C     WITH PINK BOLLWORM LARVAE, FNFST, AS A FUNCTION OF IDATE,THE
C     GIVEN JULIAN DATE THROUGH THE GROWING SEASON.
C
      X=IDATE
      IF(IDATE.LE.196) FNFST=0.
      IF(IDATE.GT.196 .AND. IDATE.LE.260)
     1   FNFST=CUBIC(-.797514E3,.139897E2,-.812771E-1,.156481E-3,X)
      IF(IDATE.GT.260 .AND. IDATE.LE.270)
     2   FNFST=CUBIC(.829357E5,-.952163E3,.363469E1,-.460758E-2,X)
      IF(IDATE.GT.270 .AND. IDATE.LE.290)
     3   FNFST=CUBIC(-.271272E5,.270758E3,-.894644,.984191E-3,X)
      IF(IDATE.GT.290) FNFST=157.
      FNFST=FNFST/100.
      RETURN
      END
```

Figure 13m.--INFEST subroutine for insecticide (fig. 8).

```
C     INSECTICIDE TREATED
      SUBROUTINE INFEST(IDATE,FNFST)
C
C             THIS SR INFEST COMPUTES THE FRACTION OF GREEN BOLLS
C     INFESTED WITH PINK BOLLWORM LARVAE, FNFST, AS A FUNCTION OF
C     IDATE, THE GIVEN JULIAN DATE THROUGH THE GROWING SEASON FOR
C     A FIELD THAT HAS BEEN TREATED WITH INSECTICIDES.
C
      X=IDATE
      IF(IDATE.LE.210) FNFST=0.
      IF(IDATE.GT.210 .AND. IDATE.LE.260)
     1   FNFST=CUBIC(-.864694E3,.142253E2,-.766568E-1,.135904E-3,X)
      IF(IDATE.GT.260 .AND. IDATE.LE.270)
     2   FNFST=CUBIC(.301939E5,-.344143E3,.130168E1,-.163120E-2,X)
      IF(IDATE.GT.270)
     3   FNFST=CUBIC(-.368443E4,.322828E2,-.924868E-1,.899986E-4,X)
      FNFST=FNFST/100.
      RETURN
      END
```

Figure 13n.--BOLMAT subroutine (fig. 3).

```
      SUBROUTINE BOLMAT(IDATE,AVDA)
C
C             SR BOLMAT COMPUTES THE NUMBER OF DAYS FROM FLOWERING
C     TO WHEN 50% OF THE BOLLS MATURE, AVDA, AS A FUNCTION OF THE
C     JULIAN DATE OF FLOWERING, IDATE.
C
      X=IDATE
      AVDA=CUBIC(.207076E2,.384656,-.271254E-2,.733372E-5,X)
      RETURN
      END
```

Figure 13o.--DIPAS subroutine (fig 9).

```
      SUBROUTINE DIPAS(IDATE,FDIPAS)
C
C             SR DIPAS COMPUTES THE FRACTION OF PINK BOLLWORM LARVAE
C     ENTERING DIAPAUSE, FDIPAS, AS A FUNCTION OF JULIAN DATE THROUGH
C     THE GROWING SEASON, IDATE.
C
      X=IDATE
      IF(IDATE.LE.235) FDIPAS=0.
      IF(IDATE.GT.235 .AND. IDATE.LE.240)
     1   FDIPAS=CUBIC(-.109131E6,.142503E4,-.620037E1,.898959E-2,X)
      IF(IDATE.GT.240 .AND. IDATE.LE.260)
     2   FDIPAS=CUBIC(.145285E6,-.175517E4,.705045E1,-.941433E-2,X)
      IF(IDATE.GT.260 .AND. IDATE.LE.265)
     3   FDIPAS=CUBIC(-.357154E6,.404221E4,-.152472E2,.191724E-1,X)
      IF(IDATE.GT.265 .AND. IDATE.LE.300)
     4   FDIPAS=CUBIC(-.430473E3,.382375E1,-.797812E-2,.356943E-5,X)
      IF(IDATE.GT.300) FDIPAS=95.
      FDIPAS=FDIPAS/100.
      RETURN
      END
```

Figure 13p.--DIES subroutine for calendar conversion.

```
      SUBROUTINE DIES(ID,MO,IYR)
C
C                 CALENDAR CONVERSION
C     IF MO EQ 0, THIS SR DIES RETURNS DATE FROM DAY OF YEAR AND YEAR
C     IF MO NE 0, THIS SR DIES RETURNS DAY OF YEAR FROM DAY, MONTH,
C     AND YEAR, LEAP YEARS CORRECTED.
C
C                 FROM G. F. BYRNE, AG. MET. 15(1975)419.
C
      DIMENSION MON(12)
      MON(1)=31
      MON(2)=28
      MON(3)=31
      MON(4)=30
      MON(5)=31
      MON(6)=30
      MON(7)=31
      MON(8)=31
      MON(9)=30
      MON(10)=31
      MON(11)=30
      MON(12)=31
      IL=IYR/4
      YL=FLOAT(IYR)/4.
      IF((YL-FLOAT(IL)).LT. .01) MON(2)=MON(2)+1
      I=0
      IF(MO.GT.0) GOTO 4
    2 I=I+1
      ID=ID-MON(I)
      IF(ID-0) 3,3,2
    3 ID=ID+MON(I)
      MO=I
      RETURN
    4 I=I+1
      ID=ID+MON(I)
      IF(MO-I) 4,5,4
    5 ID=ID-MON(I)
      MO=0
      RETURN
      END
```

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